GOVERNMENT OF INDIA

MINISTRY OF IRRIGATION AND POWER

REPORT

of the

Narmada Water Resources Development Committee

September 1, 1965

No. NC/1/65

RAJ BHAVAN

Bhubaneswar, the 1st September, 1965

FROM

The Chairman,
Narmada Water Resources Development Committee

TO

The Secretary to the Government of India,
Ministry of Irrigation and Power,
New Delhi.

SUBJECT—Narmada Water Resources Development Committee

REFERENCE—Ministry of Irrigation and Power Resolution No. DW. II-32 (4)/64, dated the 5th September 1964.

SIR,

I enclose the report of the Narmada Water Resources Development Committee for the consideration of the Government of India.

I suggest that the Government of India convey their appreciation, through the Government of Orissa, to the Superintendent of the Government Press, Cuttack, Shri U. N. Misra, and his colleagues for their courtesy, resourcefulness and efficiency in printing this report, including 27 plates, in less than a fortnight.

Yours faithfully,
Sd. A. N. KHOSLA
Chairman
Narmada Water Resources Development Committee

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INTRODUCTION

The Narmada River

The Narmada is the largest river in Central India and drains an area of about 38,000 square miles. During its course of over 800 miles to the sea it runs mostly through hilly and rocky country, and has a fall of about 3,400 feet.

As the rainfall in the catchment is good, the Narmada has an average runoff of nearly 36 million acre feet per year at Navagam where it leaves the hills and gorges and enters the flat country of Broach district in Gujarat State.

The rocky and mountainous country has many sites where storage dams for impounding water for irrigation and power generation can be built. Till 1947, however, when the country became independent, no development had taken place on the main river or on any of its important tributaries.

Past investigations

The idea of the integrated development of the Narmada basin for irrigation, power, flood control, navigation, fisheries, etc. was first mooted in 1945-46 by Shri A. N. Khosla, Chairman, Central Waterways, Irrigation and Navigation Commission. In 1946, at the request of the States concerned, a study of topography and preliminary reconnaissance were undertaken and seven sites were considered suitable for detailed investigation and preparation of projects.

In 1948, an *ad hoc* Committee under the Chairmanship of Shri A. N. Khosla, was appointed by the Government of India to scrutinise the estimates prepared for the investigation of the above seven projects, and to recommend priorities.

This Committee, after studies and discussions with officers concerned, recommended that detailed investigation should be done for Bargi, Punasa and Tawa projects in Madhya Pradesh and Broach Barrage and Canal project in the former Bombay State.

This work was taken up by the Central Waterways, Irrigation and Navigation Commission (now the Central Water & Power Commission) and project reports for Punasa, Tawa and Broach projects were prepared. Work on the Bargi had to be suspended for want of funds but this was restarted in 1960 and completed in 1963.

The Tawa project was sanctioned and work on it was started about three years back but progress has been slow on account of paucity of funds. No further progress has been made on the other three projects.

The site and scope of the Broach Barrage and Canal project have since undergone radical change. Investigations on the finally revised proposal are in an advanced stage.

The Committee

The present Committee was appointed by the Government of India in September 1964, to study the entire Narmada basin and to prepare, with the help of the Central Water & Power Commission, a Master Plan for the optimum and

integrated development of the water resources of the Narmada river for irrigation, power generation, navigation, flood control, etc.

Shortly after the appointment of the Committee, the work of organising its Secretariat and collection of reports and data from the Central Water & Power Commission, and other sources was taken up.

Shri K. S. S. Murthy, Deputy Secretary, Ministry of Irrigation & Power, acted as the Secretary of the Committee in addition to his own duties. The services of Sarvashri R. L. Mohan, Under-Secretary, Ministry of Irrigation & Power; T. A. Deodas and H. J. Desai, Deputy Directors in the Central Water & Power Commission, were placed whole time at the disposal of the Committee in September, October and November, 1964, respectively.

On 14th June 1965, Shri K. S. S. Murthy had to go abroad. Thereafter the work of the Committee had to be performed by the other three officers.

Analysis of data made available

All the available project reports for Narmada basin were collected and in response to the Committee's request, the States of Madhya Pradesh, Maharashtra, Gujarat and Rajasthan sent numerous reports, notes, memoranda and other literature explaining their view-points and giving details of their projects and the benefits they expected to derive from Narmada basin development. A large number of comments were also received from the States dealing with the project reports, memoranda and views expressed by the other States. Comments were also received from all the States on the hydrology of the Narmada originally prepared by the Central Water & Power Commission.

All these papers were carefully seen and analysed in the Committee's Secretariat and numerous additional studies were made (with the help of the Central Water & Power Commission, where necessary) and a large number of graphs, tables and statements were prepared to enable the Committee to make a realistic assessment of the view-points and needs of the various States for the preparation of the Master Plan.

The literature received from the States showed that in a few cases fairly detailed investigation had been done, in others only preliminary work had been carried out, while in the majority of cases, no investigation whatsoever had been undertaken.

The Master Plan

Owing to inadequacy of data and general lack of field investigations and project reports, considerable difficulty was experienced in coming to conclusions. But there was enough material to enable the Committee, with the help of personal discussions with the representatives of the States concerned, to draw up a Master Plan in broad outline, which it is hoped will satisfy, in large measure, the just demands and needs of the States concerned.

In drawing up the Master Plan, the Committee was guided by the following basic considerations :—

(1) National interest should have over-riding priority

Irrespective of State boundaries, the Plan should, therefore, provide for maximum benefits in respect of irrigation, power generation, flood control, navigation, etc.

(2) Rights and interest of States concerned should be fully safeguarded subject to (1) above ;

(3) Requirements of irrigation should have priority over those of power ;

subject to the provision that suitable apportionment of water between irrigation and power may have to be considered, should it be found that, with full development of irrigation, power production is unduly affected ;

(4) Irrigation should be extended, with the waters available, to the maximum area within physical limits of command irrespective of State boundaries ;

In particular, irrigation should be extended to the arid areas along the International border with Pakistan both in Gujarat and Rajasthan to encourage sturdy peasants to settle in these border areas—later event have confirmed the imperative need for this—and

(5) All available water should be utilised to the maximum extent possible for irrigation and power generation ;

and, where no irrigation is possible, for power generation ; and

the quantity going waste to the sea without doing irrigation or generating power should be kept to the unavoidable minimum.

In accordance with the above, it is proposed to extend irrigation to areas of Gujarat (Rann of Kutch) and Rajasthan (Barmer and Jalore desert) which border on Pakistan and to settle on them sturdy peasants on a permanent basis. These areas have no source of irrigation, except from the Narmada river and that with a canal taking off from Navagam at +300 FSL. This is an essential component of the Master Plan both from point of view of national security and food production in these rainless areas.

Fortunately, the available supplies in the Narmada are enough to meet all the irrigation requirements of Madhya Pradesh and Gujarat and, for want of command, only to a limited extent, those of Rajasthan. The irrigation requirements of Maharashtra from the Narmada are insignificant—only 0·10 million acre feet. The remaining areas of Rajasthan desert bordering on Pakistan, not included for irrigation from the Narmada waters, are proposed to be irrigated from the Mahi-Sabarmati complex in integration with the Narmada irrigation system in Gujarat.

The irrigation requirements at full development of Madhya Pradesh have been assessed at 15·6 MAF for 6·5 million acres of irrigation and that of Gujarat 10·65 MAF and Rajasthan 0·25 MAF for 4·68 million acres of irrigation. These requirements, according to Committee's analysis, will be met in 95 per cent of the years while in 5 per cent of the years, there will be a small shortage in Madhya Pradesh and a somewhat bigger shortage in Gujarat.

Stress has been laid in the Plan on adequate drainage facilities and resort to large-scale pumping to obviate the hazards of water-logging resulting from irrigation on a big scale. The greater the consumptive use for irrigation, the greater will be the regeneration from surface and sub-surface drainage, thereby adding to

the quantity of water available for generation of power. Large scale pumping in areas of high subsoil water levels, will similarly release corresponding surface reservoir supplies for generation of additional power.

The Plan provides for the construction of a high dam for a terminal reservoir at Navagam with FRL +500 which has been found to be the optimum level for providing the maximum storage and reducing to the minimum the amount of water wasted to the sea. This will also result in the maximum generation of power and maximum flood control. The relative benefits and economics of a dam or combination of dams at other sites in the Navagam-Hiranphal gorge have been considered. The Navagam site and the construction of a dam at this site with FRL+500, have been accepted as being the most economical, giving the maximum benefits.

The construction of the terminal and other storage dams would involve large scale submersion of lands of which between 40 to 50 per cent may be cultivable and , therefore, pose a major human problem. But if this problem is dealt with in a human way as set forth in Chapter XIV, the displaced persons will move from their original rainfed lands to lands provided with irrigation, and to model new villages with safe drinking water, electricity, roads, schools, etc. and small industries which, between them, will transform the present exclusively agricultural economy of these persons to an agro-industrial one.

The amount of power generated under the Master Plan, 20 years from the start of construction, will be 2014 MW, of which 951 MW will be at the terminal dam at Navagam. This power development will be very large in the earlier years, when irrigation is still developing, as the consumptive use of water will be small and the bulk of the river supplies will be available for power generation.

Assuming that authorisation to start essential preliminaries on the key projects of the Plan is given in 1965, the power picture, on the assumption that irrigation development will take place according to plan, will be somewhat as given below. If irrigation development is slower, the power development will be correspondingly higher.

Power development in MW on Narmada system

(Implementation of Plan assumed to start in 1965)

	1975	1980	1985	1990	1995
At Navagam ..	1054	1140	951	696	511
Above Navagam ..	554	1198	1063	843	793
Total ..	1608	2338	2014	1539	1304
Water flowing to sea without generating power MAF	7·15	6·11	6·02	5·95	5·60

The figures of power generation given in this table will be higher if allowance is made (*a*) for the regeneration water increasingly coming back into the river with increasing irrigation and (*b*) for extensive supplemental supplies pumped from the subsoil water reservoirs created by increasing irrigation. Both these additional supplies will add increasingly to power generation (indicated in the table) with increasing consumptive use for irrigation.

The load forecasts of Maharashtra, Gujarat and Madhya Pradesh show that the power will be used up as fast as it is generated. For that reason it has been proposed to instal the ultimate capacity at each dam simultaneously with its completion so that the large amount of water available from storage, while irrigation is still in the early stages of development, does the maximum amount of generation of power before being allowed to flow into the sea.

It may be mentioned here that the full cost of the Navagam dam allocated to power and of the electrical installations, which latter include the cost of 400 KV transmission lines from Navagam to Hiranphal, will have been recovered in the 26th year after start of construction and thereafter there will be a net profit to the project, after paying for depreciation and working expenses (there will be no interest charge after the 26th year as the full investment will have been recovered) of Rs. 4·71 crores per year, assuming a sale rate of 3 paise per unit (KWH) at the bus-bars. This unit rate of 3 paise allows for the extra cost of 400 KV transmission lines from Navagam to Hiranphal.

Navigation would be feasible from the mouth of the Narmada in the Gulf of Cambay and from the Kandla port, to the Navagam reservoir and beyond to the Bargi reservoir and possibly further up. It is proposed that navigation works should be constructed simultaneously with the canal works and dams so that the facilities of canals and reservoirs can be used for navigation as soon as these are completed.

The periodic floods which devastate the Narmada valley in Gujarat would cease as the storage in the several dams proposed on the river, which will be up to 28·2 million acre feet, would moderate the peak discharge to safe limits.

The reservoirs formed by the major and medium projects should, with proper management, produce vast quantities of fish, a valuable food which is in short supply and has to be imported at considerable cost in foreign exchange.

The more important dams, such as Punasa and Navagam, with small extra expense, can be developed as attractive tourist resorts.

Acknowledgements

The Committee are deeply grateful to the State Governments of Madhya Pradesh, Maharashtra, Gujarat and Rajasthan for their co-operation and assistance, for the hospitality and courtesy received during the Committee's tours and for the arrangements made for their visits to sites of work.

The Committee would like to place on record their appreciation of the excellent work done by the officers of their Secretariat. Shri K. S. S. Murthy, the Secretary, spent much time and labour in organising the work of the Committee from the start, obtaining a large mass of data and information from States and other Central

Departments, arranging for various complicated studies to be made in the Central Water & Power Commission and in the Committee's office, preparing notes for the report, etc. All this he did in addition to his normal duties as Deputy Secretary in the Irrigation and Power Ministry. Shri K. S. S. Murthy had, however, to go abroad on 14th June, 1965.

The major burden of work of collecting and collating data thereafter, and preparing material for the final report fell on Shri R. L. Mohan on the administrative side and Sarvashri H. J. Desai and T. A. Deodas on the technical side. For the last two months, they had to work long hours, often through nights, in making voluminous comparative studies, analysing data, preparing numerous tables, statements, plans and graphs, writing notes and drafts for the Committee's report and going through the proofs of the final report. The work of these officers has been arduous and has been carried out with remarkable zeal and efficiency. The Committee have much pleasure in placing on record high appreciation of the work of these officers.

The Committee would like to thank the Central Water & Power Commission for the great help they have rendered in the Committee's work.

The Committee would also like to thank the Ministry of Irrigation & Power for their co-operation and prompt assistance throughout the duration of the Committee's work.

Sd. A. N. KHOSLA
19-8-1965
Chairman

Sd. MOTI RAM
19-8-1965
Member

Sd. G. PANDE
24-8-1965
Member

Sd. H. R. BHATIA
25-8-1965
Member

Sd. U. ANANDA RAU
19-8-1965
Member

CHAPTER 1

APPOINTMENT OF COMMITTEE AND TERMS OF REFERENCE

1·1 The Committee was appointed by the Ministry of Irrigation & Power, Government of India, on the 5th September, 1964 and its composition and terms of reference were set out in the following resolution.

RESOLUTION

[No. DW. II-32(4)/64, dated the 5th September, 1964]

"The development of Narmada Valley basin has been under consideration of the Government of India and State Governments concerned for some years past. Investigations have been carried out for a number of years and considerable data has been collected. Various proposals for construction of dams, power houses and canal systems have been made from time to time for the development of the different reaches of the river. Proposals relating to the entire river have to be examined with a view to evolving best possible Master Plan for the utilisation of Narmada waters for irrigation, power development, navigation, flood control etc., in the most economical manner. It has, therefore, been decided to set up a Committee as follows :—

The Committee shall consist of—

(1)	Dr. A. N. Khosla, Governor of Orissa.	.. Chairman
(2)	Shri Moti Ram, Retd. Chief Engineer, U. P.	.. Member
(3)	Shri G. N. Pande, Vice-Chancellor, Roorkee.	.. Member
(4)	Shri H. R. Bhatia, Retd. Chairman, Punjab State Electricity Board.	Member
(5)	Shri U. Ananda Rao, Retd. Chief Engineer, Madras.	Member
(6)	Shri K. S. S. Murthy, Deputy Secretary, Ministry of Irrigation & Power.	Secretary

The terms of reference of the Committee shall be —

(*a*) to collect, with the assistance of the Central Water & Power Commission and the State Governments of Madhya Pradesh, Maharashtra and Gujarat, the relevant reports, correspondence and data and draw up a Master Plan for the optimum and integrated development of the Narmada water resources;

(*b*) in consultation with the three State Governments recommend the projects to be taken up in the first instance, and the order in which they should be started so that after execution of the first group the further development of the valley becomes self-financing, if possible, and provide maximum benefits to the State concerned ;

(*c*) to examine in particular Navagam project together with alternative projects, if any, and suggest appropriate full reservoir level and consequential adjustments ;

(*d*) to suggest the distribution of benefits and costs among the States; and

(*e*) to make recommendations on any other ancillary matters.

The Committee shall submit its report within four months.

The Committee shall have its headquarters at New Delhi."

Implementation of the Resolution

1·2 As the Committee proceeded with this work it soon became apparent, as explained below, that its deliberations could not be completed within the period of four months allowed to it. The term of the Committee had, therefore, to be extended from time to time.

A large amount of data together with plans and reports was prepared and furnished by the various States which included, in some cases, completely new proposals. After examination of the voluminous material, fresh information was asked for and obtained. The data and reports sent by each State were sent to the other States for their information, and comments received had to be examined by the Committee. In serveral cases rejoinders on the comments were also received.

The Committee carried out an extensive tour of Madhya Pradesh and Gujarat in April, 1965 to inspect sites of the principal dams and to discuss various aspects of development with the two Governments and public bodies interested. Discussions were held with the Government of Maharashtra in June, 1965 in connection with the proposals submitted by that State. Discussions were similarly held with the Government of Rajasthan in July, 1965. The last round of discussions with the Chief Ministers of Madhya Pradesh and Gujarat was held in July and August, 1965, respectively. Discussions were also held with officers of Madhya Pradesh on 6th and 7th August and again with officers of Madhya Pradesh, Gujarat and Maharashtra on 15th and 16th August, 1965.

CHAPTER II

MEETINGS, TOURS AND DISCUSSIONS

2·1 The first meeting of the Committee was held on the 3rd and 4th October, 1964 at New Delhi for preliminary discussions. Subsequent meetings were held at intervals of one to two months. The interval between the various meetings was utilised for studying the existing data, collection of new data, interchange of data among the three States of Madhya Pradesh, Maharashtra and Gujarat and the State of Rajasthan and for obtaining their views thereon. The dates of various meetings are given below :—

Meeting	Date
First meeting	3—4 October, 1964
Second meeting	7—9 November, 1964
Third meeting	14—18 December, 1964
Fourth meeting	2—5 February, 1965
Fifth meeting	3—4 April, 1965
Sixth meeting	4—11 May, 1965
Seventh meeting	1—4 July, 1965
Eighth meeting	16—19 July, 1965
Ninth meeting	31st July to 6th August, 1965
Tenth meeting	13—22 August, 1965

2·2 The first two meetings were devoted to the examination of the data and correspondence already received and study of documents readily available. Thereafter, the States were asked to meet the Committee with additional data and information required by the Committee as well as any other data that the State Governments themselves wished to place before the Committee.

2·3 The Committee, at its third meeting, decided that the data and information to be furnished by each State would be supplied to the other States who would be free to offer their comments.

2·4 Discussions were held with the State representatives during the third and the fourth meetings of the Committee. Madhya Pradesh representatives met the Committee on the 14th and 15th December, 1964, Gujarat representatives on the 16th and Maharashtra and Rajasthan representatives on the 17th. Shri Hamzah Ali, Superintendent Geologist of the Geological Survey of India, met the Committee on the 18th December, 1964 and explained the geology of the Navagam Dam site.

2·5 At the fourth meeting held in the first week of February, 1965, the Committee circulated to the State representatives a tabulated statement containing the tentative studies carried out by the Committee's secretariat and also the hydrological studies carried out by the Central Water and Power Commission. Preliminary discussions were held with the State representatives about the hydrological data available as well as the approach and method for further studies in this regard. The State Governments were requested to send their draft Master Plans before the 1st of March, 1965.

2·6 At the fifth meeting, the Committee examined various studies about hydrology and power development with various heights and combinations of dams and generally discussed the irrigation proposals of the States.

2·7 The Committee undertook an inspection tour of some of the project sites and areas proposed to be irrigated by the Narmada waters, from the 5th to 10th April, 1965. Representatives of Madhya Pradesh, Maharashtra and Gujarat accompanied the Committee during this tour of inspection. The detailed tour programme and list of participants can be seen at Annexures II-1 and II-2.

2·8 The Committee met the Chief Minister and other Ministers of Maharashtra Government at Bombay on the 10th June, 1965, and had discussions with them on the various aspects of Narmada development. The Committee also met the Chief Minister and other Ministers of Rajasthan Governmentat Jaipur on the 18th July, 1965 for similar discussions.

2·9 At Bhopal and Ahmedabad, the Committee held discussions with the Chief Ministers and other Ministers of Madhya Pradesh and Gujarat, respectively. At Bhopal, the Chief Minister and the Irrigation Minister of Maharashtra were also present during the discussion.

2·10 Apart from the full scale discussions the Committee had with the State representatives as mentioned above, Shri Moti Ram, Member, had detailed discussions with officers of Gujarat on the 10th March, 1965 at New Delhi, regarding the crop pattern and water requirements under the proposed Navagam Project.

2·11 At the sixth meeting, the Committee discussed in detail the crop patterns and water requirements of the States, the site and height of the main dam in the lower reach of the river for optimum utilisation of water and maximum generation of power, the level of the Narmada canal at Navagam and the sharing of costs, benefits, etc.

2·12 The last four meetings of the Committee were devoted to the studies of various alternatives and finalising their report.

2·13 Documents, literature, maps and other data, received from various State Governments as well as those obtained from the Central Water and Power Commission and other sources are listed in Annexure II-3. The list also indicates the dates on which these were received or obtained. It will be seen that some of the comments and observations reached the Committee as late as June, 1965. Some communications were received in July 1965.

ANNEXURE II-1

DETAILS OF THE VISIT OF THE NARMADA COMMITTEE TO MADHYA PRADESH, GUJARAT, MAHARASHTRA AND RAJASTHAN

5th April, 1965 ..	Bhopal	..	Discussions with the Chief Ministers and other Ministers of Madhya Pradesh and Maharashtra.
			Discussions with M..Ps. and M. L. As. of Madhya Pradesh.
6th April, 1965 ..		..	Visited Bargi Project site
	Jabalpur	..	Visited Jawaharlal Nehru Agricultural University and held discussions with the Vice-Chancellor and staff on crop pattern and water requirements.
			Visited Jamtara Gauging site
7th April, 1965 ..		..	Visited Punasa Dam site
	Khandwa	..	Meeting with deputation of cultivators/M.Ps./M. L. As. of Madhya Pradesh.
8th April, 1965 ..		..	Visited Gardeshwar Gauging site
			Visited Navagam Project site
9th April, 1965 ..		..	Visited Nikora Farm
	Baroda	..	Meeting with Krishak Samaj, Federation of Industries and Municipality.
10th April, 1965 ..	Ahmedabad	..	Discussions with M. Ps. and M. L. As. of Gujarat
			Meeting with Chamber of Commerce and Industries
			Discussions with Chief Minister and other Ministers of Gujarat.
10th June, 1965 ..	Bombay	..	Discussions with Chief Minister and other Ministers of Maharashtra.
18th July, 1965 ..	Jaipur	..	Discussions with Chief Minister and other Ministers of Rajasthan.

ANNEXURE II-2

LIST OF STATE OFFICERS WHO ACCOMPANIED THE COMMITTEE ON THEIR TOUR OF INSPECTION OF MADHYA PRADESH AND GUJARAT

Madhya Pradesh

1. Shri M. A. Khan, Secretary, Public Works Department
2. Shri N. D. Gulhati, Consultant
3. Shri M. L. Sood, Irrigation Adviser
4. Shri S. N. Mehta, Chairman, State Electricity Board
5. Shri N. Tata Rao, Chief Engineer and Secretary, State Electricity Board
6. Shri R. L. Gupta, Superintending Engineer
7. Shri Matin Ahmed, Officer on Special Duty
8. Dr. T. S. Gill, Director of Agriculture

Gujarat

1. Shri G. G. Dhanak, Chief Engineer
2. Shri M. N. Jathal, Superintending Engineer
3. Shri D. M. Patel, Superintending Engineer
4. Shri S. M. Khubchandani, Executive Engineer
5. Shri R. G. Subramaniam, Executive Engineer

Maharashtra

1. Shri K. C. Nayar, Secretary, Irrigation & Power Department
2. Shri G. N. Pandit, Chairman, State Electricity Board
3. Shri P. M. Mane, Chief Engineer
4. Shri B. S. Apte, Superintending Engineer
5. Shri B. S. Khapre, Superintending Engineer

ANNEXURE II-3

LIST OF DOCUMENTS RECEIVED FROM THE STATE GOVERNMENTS AND THE CENTRAL WATER AND POWER COMMISSION

		Date of furnishing
Madhya Pradesh		
MP/1.	Punasa Project Report	21-10-64
MP/2.	Plan showing levels in relation to Omkareshwar Temple	25-11-64
MP/3.	Tawa Project Report and its salient features	4-12-64
MP/4.	Barna Project Report and its salient features	Ditto
MP/5.	Sitarewa Project Report and its salient features	Ditto
MP/6.	Discharge data at Jamtara	Ditto
MP/7.	Discharge data at Mortakka	Ditto
MP/8.	Agricultural information in respect of districts covered by the Projects on the Narmada.	Ditto
MP/9.	Note for Narmada Committee	14-12-64
MP/10.	Comments on Central Water and Power Commission's note on Hydrology	20-2-65
MP/11.	Master Plan for the development of the water resources of the Narmada	27-2-65 26-3-65
MP/12.	Narmada Valley Development—Some relevant documents	7-4-65
MP/13.	Comments on Gujarat Government Memorandum and on their observations on Maharashtra Government Memorandum.	29-5-65
MP/14.	Rejoinder to observations by Gujarat on the Madhya Pradesh Master Plan and comments on other documents submitted by Gujarat.	5-6-65
Gujarat		
G/1.	Broach Project Report	21-10-64
G/2.	Observations of the Central Designs Organisation (Bombay Government), on Broach Project Report.	Ditto
G/3.	Consultants' Report on Broach Project	Ditto
G/4.	Navagam Project Report	1-11-64
G/5.	Hydrological studies for Narmada Project	18-11-64
G/6.	Geological Report for Navagam Dam site No. 3	Ditto
G/7.	Monthly Discharge Data at Gardeshwar (1948—1963)	Ditto
G/8.	Hydro-Meteorological Year Book, 1962	18-11-64
G/9.	Hydro-Meteorological Year Book, 1963	Ditto

		Date of furnishing
G/10.	Command Map of Gujarat State (1"=4 miles) indicating proposed alignment of Narmada High Level Canal and its command.	18-11-64
G/11.	Agricultural information for the command of Narmada Project	1-12-64
G/12.	Report of Fact Finding Committee, 1960	Ditto
G/13.	Report on Reclamation of Little Rann of Kutch	Ditto
G/14.	Study of Soils in the Rann of Kutch	Ditto
G/15.	Soil Survey Report on the command areas under Narmada Low Level Canal.	Ditto
G/16.	Technical Memorandum submitted to Narmada Committee	27-1-65
G/17.	Comments on documents forwarded by Narmada Committee	Ditto
G/18.	Comments on note submitted by Madhya Pradesh Government	26-2-65
G/19.	Note on the possibilities of reclamation and irrigation of Great Rann of Kutch.	6-3-65
G/20.	Note on water requirements for irrigation from Narmada Project in Gujarat State.	10-3-65
G/21.	Comments on C. W. & P. C's. note on Hydrology	20-3-65
G/22.	Comments on draft studies by Committee Secretariat on alternative proposals for Narmada.	Ditto
G/23.	Comments on Maharashtra Government Memorandum	4-4-65
G/24.	Comments on Rajasthan Government Memorandum	27-4-65
G/25.	Comparative study of two canals at F. S. Ls. 300 and 210 *versus* one canal at F. S. L. 300 from Navagam Reservoir.	3-5-65
G/26.	Water resources of all the rivers crossed by Narmada Canal and proposals for their utilistion.	Ditto
G/27.	Brief inspection note on Ambadongar flourite deposits in Navagam Dam site area by Shri Hamzah Ali.	Ditto
G/28.	Habitation and cultivation of the areas in Great Rann of Kutch	Ditto
G/29.	Tubewell possibilities in Gujarat State	Ditto
G/30.	Mahi Project Report	Ditto
G/31.	Observations on the Master Plan proposed by Madhya Pradesh	7-5-65
G/32.	Salient features of irrigation projects in Gujarat State	27-5-65
Maharashtra		
M/1.	Memorandum on the development of the Narmada resources below Punasa up to Navagam.	27-2-65
M/2.	Note on development of water resources of the Narmada	5-5-65
M/3.	Note on optimum canal off-take level from the Navagam low Dam for full utilisation of the available water resources of Narmada.	10-6-65

Rajasthan		Date of furnishing
R/1.	Note on utilisation of Narmada waters for irrigation & power in Rajasthan.	17-12-64
R/2.	Mahi Valley Development Scheme—Note on providing irrigation facilities in South-Western Region of Rajasthan.	3-5-65

Central Water and Power Commission

CWPC/1. Studies for estimating runoff on the Narmada by rational formula

CWPC/2. Estimation of annual yields of Narmada at Punasa, Barwaha, Hiranphal and Navagam.

CWPC/3. Note on hydrological studies on the Narmada

CWPC/4. Note on Reduction co-efficient for converting surface velocity to mean velocity.

CWPC/5. Hydrological studies on the Narmada on a zonal basis

CHAPTER III

NARMADA RIVER SYSTEM

3·1 The Narmada River rises on the Amarkantak Plateau at the north-eastern apex of the Satpura range, at an altitude of 3,468 ft. and, after traversing a total course of about 815 miles in a westerly direction, it merges with the Arabian Sea in the Gulf of Cambay, draining an area of nearly 38,000 sq. miles in the States of Madhya Pradesh, Maharashtra and Gujarat.

3·2 About 5 miles from its source, the river drops through 70 to 80 ft. at the Kapildhara falls and two furlongs further downstream it again drops by about 15 ft. at the Dudh-dhara Falls.

3·3 At 178 miles from the source, the river turns in a narrow loop northwards and flows for some distance in a number of channels called Sahasradhara. BARGI dam site is located at 235 miles from the source. Close to Jabalpur, at about 251 miles from the source, the river has a fall of nearly 50 ft. at Dhuandhar, after which it flows through a narrow channel carved out by it through the famous marble rocks.

3·4 Emerging from the marble rocks, the Narmada enters the fertile lands of the Great Narmada Plain lying in Jabalpur and Hoshangabad districts which is said to be the best wheat growing tract of India.

3·5 At Mandhar, 501 miles from the source and at Dhardi, 29 miles further downstream, the Narmada drops over falls of 40 ft. at each place. Nearly 21 miles below Mandhar Falls, *i. e.* 522 miles from the source, the PUNASA dam site is located. The BARWAHA dam site lies about 30 miles downstream of Punasa. About 4 miles downstream of Maheshwar, *i. e.* nearly 600 miles from source, there is another fall of about 25 ft. known as Sahasradhara Falls.

3·6 650 miles from the source—at * HIRANPHAL—the Narmada enters a 70 mile long gorge, where the Vindhyas and Satpuras almost converge, the ranges being separated by the river itself.

3·7 For 20 miles below Hiranphal, the Narmada flows in the State of Madhya Pradesh, and from there onwards it forms the common boundary between the States of Madhya Pradesh and Maharashtra. 34 miles below Hiranphal is located the JALSINDHI site, and 8 miles further down, that is 42 miles from Hiranphal, starts the common boundary between Maharashtra and Gujarat.

3·8 For the next 24 miles, the Narmada separates the States of Maharashtra and Gujarat, and two miles downstream of the common boundary lies the NAVAGAM site—718 miles from source—situated wholly in Gujarat. Below the common boundary the river continues to flow for another hundred miles through the Gujarat plains until it joins the Arabian Sea.

3·9 Table 3·1 indicates the districtwise distribution of the catchment area of the Narmada basin in the three States *viz.*, Madhya Pradesh, Maharashtra and Gujarat and Table 3·2 gives the list of major tributaries of the Narmada,

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*NOTE—Although Haranphal or Harinphal are the names commonly used for this site, Hiranphal has been used in this report as adopted by the Survey of India.

their lengths, catchment areas, etc. The course of the river and the political divisions are shown in Plate III-1. The longitudinal section of the river is shown in Plate III-2.

TABLE 3·1

Districtwise distribution of catchment area of Narmada Basin

Sl. No.	Name of State	Name of District	Catchment area in sq. miles	Remarks		
1.	Madhya Pradesh.	Shahdol	252			
		Mandla	4,370			
		Durg	276			
		Balaghat	992			
		Seoni	1,002			
		Jabalpur	2,280			
		Narsinghpur	1,923			
		Sagar	268			
		Damoh	172			
		Chhindwara	1,420			
		Hoshangabad	3,845			
		Betul	1,490			
		Raisen	1,873			
		Sehore	1,409			
		East Nimar	2,780			
		West Nimar	4,637			
		Dewas	1,447			
		Indore	441			
		Dhar	1,890			
		Jhabua	383	Total C. A. in M. P.	33,150	sq. miles
2.	Maharashtra	West Khandesh	594	Total C. A. in Maharashtra.	594	sq. miles
3.	Gujarat	Baroda	2,270			
		Broach	2,021			
		Surat	80	Total C. A. in Gujarat.	4,401	sq. miles
		Panchamahal	30			
			38,145 sq. miles			

TABLE 3·2

List of Major Tributaries of the Narmada

Sl. No.	Name of Tributary	Distance of confluence with Narmada from source	Length of Tributary	Catchment Area in sq. miles
		Miles		
Right Bank				
1.	Hiran ..	288	117	1,850
2.	Tendoni ..	374	73	630
3.	Barna ..	376	65	690
4.	Kolar ..	646	63	520
5.	Man ..	620	55	590
6.	Uri ..	643	46	700
7.	Hatni ..	668	50	750
8.	Orsang ..	740	63	1,575
Left Bank				
1.	Burhner ..	154	110	1,590
2.	Banjar ..	178	114	1,400
3.	Sher ..	309	80	1,120
4.	Shakkar ..	339	100	885
5.	Dudhi ..	357	80	595
6.	Tawa ..	420	107	2,445
7.	Ganjal ..	470	55	745
8.	Chhota-Tawa ..	515	105	1,950
9.	Kundi ..	586	75	1,475
10.	Goi ..	645	80	730
11.	Karjan ..	745	58	575

CHAPTER IV

HISTORICAL REVIEW

4·1 In April, 1945, the Government of India constituted the Central Waterways, Irrigation and Navigation Commission, under the Chairmanship of Shri A. N. Khosla, I.S.E., to

> "act generally as a central fact finding, planning and co-ordinating organisation with authority to undertake construction work. It will be available to advise the Central, Provincial and State Governments in regard to Waterways, Irrigation and Navigation problems throughout the country. The Commission will be a strong technical organisation designed to conduct, where necessary, surveys and investigations with a view to secure planned utilisation of the water resources of the country as a whole and in consultation with the Provincial and State Governments throughout the country, to co-ordinate and press forward schemes for the conservation, control and regulation of water and waterways and further, when so required by the Government of India to undertake the execution of any such scheme."

The Narmada River Basin was among the first considered for investigation by the Commission. In 1946, the (then) Government of Central Provinces and Berar and the (then) Government of Bombay requested the Central Waterways, Irrigation and Navigation Commission (CWINC) to take up investigations on the Narmada river system for a basinwise development of the river with flood control, irrigation, power and extension of navigation, as the general objectives in view.

4·2 Accordingly, the topography and the hydrology of the basin were taken up for study in the CWINC at the beginning of the year 1947. The study of the topography revealed excellent storage sites on the main river and some of its tributaries. Most of the sites were inspected by engineers and geologists and as a result of this preliminary reconnaissance, detailed investigation of seven projects was recommended. These projects were :—

1. Bilghara on the Narmada
2. Ghugri on the Burhner
3. Bargi on the Narmada
4. Ranipur on the Tawa
5. Punasa on the Narmada
6. Barwani on the Narmada
7. Broach Weir below gorge on the Narmada

It was expected that these projects would, on completion, produce over a million KW of continuous power and irrigate a gross command of nearly 40 lakh acres.

Ad hoc Committee 1948

4.3 In 1948 the Central Ministry of Works, Mines and Power appointed an *ad hoc* Committee consisting of Shri A. N. Khosla, Chairman, C.W.I.N.C., Dr. J. L. Savage and Shri M. Narasimhaiya to scrutinise the estimates prepared for investigations of the above projects and to recommend priorities. The *ad hoc* Committee after study and discussions with the officers, who had prepared the estimates, recommended as follows:—

"The Narmada basin appears to hold great potential of development, and such development is likely to have far-reaching effect on the economic advancement of the country in general, and the basin in particular. It appears feasible to bring under irrigation 37,00,000 acres of cultivated and cultivable land in the basin, generate continuous power of over a million KWs. and extend navigation from the river's outfall in the sea right up to and beyond Hoshangabad, i. e., almost to the heart of the country. The principal works involved would be construction of about eight storage reservoirs, a number of barrages and three systems of canals and some navigation locks.

* * * *

"At this stage we were also apprised of the views of the Secretary, Works, Mines and Power and the reactions of the Chairman, C.W.I.N.C., regarding cutting short the programme of work on account of present day shortages of men and materials. The notes on the subject are appended to this report (Appendix III). We entirely agree with this view and suggest that it will be desirable to restrict the work in the first 2-3 years to only such projects as will give the maximum results in the shortest possible time. Judged from this criterion, we recommend that investigations be concentrated on the following:—

Bargi Project—The project envisages construction of 3 dams and a system of canals to command 18,00,000 acres. It is calculated that in addition it would be possible to generate 80,000 KWs. of firm power. As most of the water will be used up for irrigation it might not be possible to make the navigational feature very attractive.

Tawa Project—This envisages construction of a dam on the tributary Tawa just above its outfall into the Narmada a few miles above Hoshangabad. A dam of 170 feet height will intercept the entire run-off from a catchment of 2,340 square miles. An area of 11,00,000 acres would be commanded from the reservoir itself for irrigation. The power potential is likely to be 12,700 KWs. (continuous).

Punasa Project—A dam of 237 feet height will intercept almost the entire residual run-off of the main river at this site. It is proposed to reserve a portion of the capacity for controlling the floods which occur frequently in the Broach district of Gujarat in Bombay Province. Taking this into account, the power potential of this project would be in the neighbourhood of 2,23,000 KWs. continuous. The lake would be navigable right up to its upper end, very near Hoshangabad.

Barrage and canal system for the Broach district—With the regulated supplies available from the Punasa Project it would be possible to command the entire cultivated area of Broach district, measuring about 8,00,000 acres for perennial irrigation.

"In addition to concentrated investigations on these projects we also recommend that the cost of collection of such essential data as discharge and silt observations at various important stations, meteorological, mineral, navigational and economic surveys and special tools and plant required should be provided for in the estimate for investigation of the projects on a basinwise basis.

"At our request fresh detailed estimates have been prepared to cover these investigations and these amount to Rs. 64,97,000. The cost will be spread over a period of three years, Rs. 26,97,000 in the first, Rs. 19,00,000 in the second and Rs. 19,00,000 in the third year.

"The strength of engineering staff provided is adequate for the purpose in view.

"While examining this project it was brought to our notice that there is a proposal to utilise the land to be commanded for irrigation by the Bargi and Tawa projects for resettling and rehabilitating refugees from Sind and Western Punjab. If, on this account, therefore, the investigations have to be speeded up, and construction has to be launched upon simultaneously, the staff for these two projects will have to be considerably strengthened to suit the pace at which progress would be demanded."

Investigations and Studies

4.4 Based on the recommendations of the *ad hoc* Committee, estimates for the investigation of Bargi, Tawa, Punasa and Broach projects were sanctioned by the Government of India *vide*, Ministry of Works, Mines & Power letter No. 18/47, dated the 19th March, 1949.

4·5 The CWINC took up investigations of these projects in the year 1949. Investigations of three projects, except Bargi, were completed and the project reports prepared. In 1951, the Central Waterways, Irrigations & Navigation Commission (CWINC) was renamed as the Central Water & Power Commission. The work of investigations of the Bargi Project, which had to be suspended for want of funds, was started again by the Central Water & Power Commission in November 1960, and project report prepared in November, 1963.

4·6 The Central Water & Power Commission carried out a study of the hydro-electric potential of the Narmada river in 1955. The report on this study pointed out that, with adequate regulation, it would be possible to generate firm power of the order of about 1·3 million KW. at the following 16 sites:—

1. Rosra
2. Basania
3. Bargi

4. Chinki
5. Hoshangabad
6. Punasa
7. Barwaha
8. Hiranphal
9. Keli
10. Goia
11. Burhner
12. Sitarewa
13. Tawa
14. Kolar
15. } On irrigation canal from Bargi
16. }

Of these, Nos. 1 to 10 are on the main river and Nos. 11 to 14 on the tributaries of the Narmada. All these sites, except Nos. 9 and 10, lie in the present Madhya Pradesh. Site No. 9 lies on the common boundary between Maharashtra and Gujarat and site No. 10 is in Gujarat.

4·7 At a meeting held on 24th September, 1957 at New Delhi attended by the representatives of Madhya Pradesh and Bombay to consider the question of comprehensive development of Narmada Valley, the Chairman, Central Water & Power Commission pointed out:-

> "Some investigation work for the Punasa Hydro-electric Scheme was conducted by C. W. & P. C. some time ago, and a report prepared. Further studies of the Power Potential of the entire Narmada Valley have revealed that, apart from Punasa Dam, sites for construction of pick up dams are available where generation of power would be feasible after construction of the Punasa Dam. There is scope also for utilisation of the water of the river for irrigation, and the Broach Scheme is currently under investigation for the purpose. Therefore, it was desirable that investigations should be carried out at the three other sites between Punasa and Broach to assess the optimum potentialities of irrigation and power. Minor modifications which may be necessary for the Punasa Project after detailed investigations as well as its repercussions on the Broach Scheme would have to be taken into consideration for finalising the Punasa and Broach Projects."

4·8 As a result of the discussions at the above meeting it was decided that investigations should be carried out at three intermediate sites between Punasa and Broach, *viz.*, at Barwaha, Keli and Hiranphal by the Central Water & Power Commission and the cost of such investigations shared equally by Madhya Pradesh and the then Bombay State.

MADHYA PRADESH PROJECTS

4·9 In addition, the Central Water and Power Commission carried out investigations for irrigation projects on two of the tributaries of the Narmada, *viz.*,

Barna and Kolar. According to all these investigations, the total irrigation development contemplated by these projects was as follows :—

Bargi	..	5,32,000 acres
Tawa	..	7,50,000 acres
Punasa	..	62,000 acres
Barwaha	..	2,18,000 acres
Kolar	..	1,23,100 acres
Barna	..	1,72,800 acres
		18,57,900 acres

4·10 Besides the above projects, the Central Water & Power Commission have carried out investigations at Hiranphal site. The State Government also have completed investigations on Sitarewa and prepared a project report. Investigations on other projects in Madhya Pradesh listed in para. 4·6 have, it is understood, not been undertaken so far.

Acreage of irrigation and water requirements

4·11 During February 1961, while finalising the Punasa Project Report, a question arose as to what should be the water reservations for upstream irrigation. There was a meeting in this connection in the Central Water & Power Commission in the room of Member (D. & R.), which was attended by Chief Engineer, Irrigation, Madhya Pradesh. It was decided at this meeting that the water requirements for upstream uses would be of the order of 6 million acre feet for irrigating an area of 30 lakh acres.

4·12 Adding the irrigation contemplated below Punasa of 2,18,000 acres, the total irrigation potential of the Narmada basin in Madhya Pradesh was estimated to be of the order of 32 lakh acres in 1961.

Subsequently, however, in a publication (1963) of Madhya Pradesh, entitled "Irrigation & Power Potential of Madhya Pradesh Rivers", it has been stated that the area that can be irrigated in Narmada basin in Madhya Pradesh is 46 lakh acres.

In the 1965 "Note on Agro-economic aspects of irrigation potential in Narmada valley, Madhya Pradesh" issued by the State Electricity Board, a figure of 50 lakh acres of irrigation requiring 15 MAF of water is mentioned.

1965 Master Plan of Madhya Pradesh

4·13 After the setting up of the Narmada Water Resources Development Committee in September 1964, the State Government have radically reviewed their policy of water resources development and in the draft Master Plan, submitted to the Committee, they have indicated that the total irrigation anticipated by Madhya Pradesh in Narmada basin will be of the order of 77·5 lakh acres.

In arriving at this figure, the State Government appear to have assumed that all lands within the command could be irrigated, in so far as the water resources permit, either by means of gravity flow or by lift, there being no limitation to the extent of lift involved. They have accordingly calculated that their water requirements for irrigation would be 23·75 MAF.

Based on the statistics of land classification of Madhya Pradesh for 1962-63, the entire sown area in Madhya Pradesh in the Narmada basin stands at 82·2 lakh acres. The Master Plan contemplates that eventually practically the entire culturable waste and fallow lands, pastures, etc. will be cultivated.

The demand for water, according to them would, therefore, be even higher in future.

The figures of irrigation and water demands of Madhya Pradesh in Narmada basin from time to time are indicated in Table 4·1.

TABLE 4·1

Irrigation and Water Demands of Madhya Pradesh in Narmada Basin

Sl. No.	Year	Area to be irrigated (lakh acres)	Total water requirements (MAF)	Average Delta (Ft.)	Reference	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	(*a*) 1961	30·00	6·00	2·00	Punasa Project report. Decision taken at a meeting held in C. W. & P. C.	For areas at and upstream of Punasa Dam.
	(*b*) 1961	2·18	1·00	4·60	Preliminary report on Barwaha Project.	For areas downstream of Punasa Dam.
	Total	32·18	7·00			
2.	1963	46·00	12·00	2·60*	Government of Madhya Pradesh publication "Irrigation & Power Potential of Madhya Pradesh Rivers"—Page 3, Table III.	*Total water requirements indicate utilisable runoff, i.e., consumptive uses including probable losses in hydel schemes (non-consumptive use), requirements of industries & domestic uses.
3.	1965	50·00	15·00	2·00	"A Note on Agro-economic Aspect of Irrigation Potential in the Narmada Valley in Madhya Pradesh", by Madhya Pradesh Electricity Board.	Envisages double-cropping to the extent of 50 per cent of the area.
4.	1965	77·50	23·75	3·06	Madhya Pradesh "Outline Master Plan for the Development of the Water Resources of the Narmada" submitted to the Committee.	

ERSTWHILE BOMBAY PROJECTS

The Broach Project

4·14 The earliest proposal for utilisation of Narmada waters in Gujarat was made in 1956, when the Central Water & Power Commission finalised their Broach Project Report. This scheme comprised a weir across the Narmada at Gora and a Right Bank Canal to irrigate 10·97 lakh acres in a gross command of 13·3 lakh acres.

The requirements of waters were estimated at 2·8 MAF.

4·15 During the course of the technical examination of the scheme some time in February, 1957, the Central Water & Power Commission suggested shifting of the weir site 1½ miles higher up, and also the provision of a high level canal to irrigate areas in the Mahi and Sabarmati basins in Gujarat. It was roughly worked out that this high level canal would irrigate 9·4 lakh acres gross and the water requirements would be of the order of 1·7 MAF.

In other words, the revised Broach Irrigation Project contemplated utilisation of 4·5 MAF of water and irrigation of 22·7 lakh acres (gross). It was contemplated that this irrigation would be done with the regulated releases from the Punasa storage.

Navagam and Keli Dams

4·16 In January, 1959, the Government of the then Bombay State under their letter No. MIP-5559-J191249, dated the 16th January 1959 addressed to the Chairman, C. W. & P. C., pointed out—

> "The Central Water & Power Commission is aware of the fact that the Navagam Dam is likely to be raised in the second stage to R. L. 300 approximately and in that event there would be no occasion for the construction of the dam at Keli in between Hiranphal and Navagam. In view of this though provision has been made in the estimate for investigation of the Keli Dam, the same, it is presumed, would not be operated upon."

4·17 The above presumption was confirmed by the C.W.&P.C. under letter No. 7 (1)/58-FFI, dated the 5th February 1959 to the Government of Bombay under intimation to the Government of Madhya Pradesh.

4·18 The revised Broach Irrigation Project was referred to the erstwhile Government of Bombay for its observations in the year 1959. While accepting the broad features of the project, as recommended by the Central Water & Power Commission, the State Government suggested certain modifications regarding spillway capacity, crop pattern, power generation, etc. The estimates were also recast in the light of the figures of cost for similar projects in the State.

4·19 This project was then referred by the Ministry of Irrigation and Power to a panel of Consultants who, in their detailed comments submitted in April 1960, made an important suggestion that the two stages of the dam should be combined into one and the dam constructed to its final FRL+300 in the first instance.

THE GUJARAT STATE

4·20 The new State of Gujarat was created on 1st May 1960.

GUJARAT PROJECTS

The Broach Project

4·21 Stage I of the Broach Irrigation Project was sanctioned by the Planning Commission in August, 1960, providing for the construction of a dam with FRL +162 with wider foundations for greater height.

4·22 Administrative approval to Stage I was accorded by the Government of the newly formed Gujarat State in February, 1961, and the work inaugurated by the late Prime Minister, Shri Jawaharlal Nehru, on the 5th April 1961 and construction of approach roads, colony, etc. was taken up.

Navagam Dam

4·23 While the above preliminary works for the project were under execution, a study was made by Gujarat about utilising the flow in Narmada in the free catchment below Punasa. Navagam being the terminal reservoir had necessarily to provide for storage of the available flow, particularly from the intervening free catchment. A careful check of the water planning and the extent of benefits that could be had by reshaping of the project was made. Studies indicated that a reservoir with FRL+460 would enable realisation of optimum benefits by utilising the untapped flow below Punasa, and would make it possible to extend irrigation to a further area of over twenty lakh acres. However, Gujarat proposed FRL+425 only for the Navagam Dam in August, 1963. According to this project, the gross commanded area was to be of the order of eighty lakh acres and annual irrigation forty lakh acres. Instead of two canals as envisaged earlier, it was proposed to take only a High Level Canal at FSL+300. The scheme was also to include reclamation of the Little Rann of Kutch and irrigate nine lakh acres (gross) there.

The gross water utilisation was estimated at 12 MAF which included 0·6 MAF towards industrial and domestic use.

1965 Proposals of Gujarat

4·24 Subsequently in January, 1965, in the technical Memorandum (Document G/16) submitted to the Narmada Water Resources Development Committee, the Gujarat Government have indicated that they would require nearly 13 MAF for a revised figure of 34·74 lakh acres (44·86 lakh acres including double-cropping) of irrigated area. The dam at Navagam has been proposed to be constructed to FRL+490.

The State Government have, in reply to an inquiry by the Chairman of the Committee, submitted a separate Memorandum (Document G/19) indicating that parts of the Great Rann of Kutch could also be irrigated from Navagam Canal and for this purpose an additional quantity of 2·45 MAF of water was needed to irrigate annually 4·5 lakh acres (7·65 lakh acres including double-cropping).

In other words, Gujarat's latest claim on Narmada waters could be taken as 15·5 MAF to provide irrigation to 39·24 lakh acres.

In support of their water requirements, they have given details and calculations about crop pattern, duties and deltas based on sanctioned project reports in Gujarat and projects elsewhere in India and also a study and information about the agricultural benefits to lands proposed to be irrigated.

4·25 Summing up, the earlier proposal of utilising 2·8 MAF of water in 1956-57 was revised to 4·5 MAF in 1959, to 12 MAF in 1963, to 13 MAF in January, 1965 and to 15·5 MAF in March, 1965.

This does not include 1·90 MAF required for 6·57 lakh acres included in the Mahi Project which can be commanded by the Navagam Canal thereby releasing equivalent water for irrigation of other areas.

The irrigation and water demands of Gujarat in Narmada basin from time to time are indicated in Table 4·2.

TABLE 4·2

Irrigation and water demands of Gujarat from Narmada

Sl. No.	Year	Area to be irrigated (lakh acres)	Total water requirements (MAF)	Average Delta at canal head (Ft.)	Reference	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	1956	10·97	2·80	2·55	Broach Project Report.	Envisages construction of a weir across Narmada at Gora.
2.	1957	22·70	4·50	2·00	Modified Broach Project Report (stage 1).	Envisages construction of a dam with FRL+300—1½ miles upstream of Gora weir site and two canals—one high level and the other low level.
3.	1963	40·00	12·00	3·00	Navagam Project Report.	Envisages construction of a dam at Navagam with FRL +425 and high level canal with FSL+300. Area includes reclamation of Little Rann of Kutch, requiring heavy waterings for leaching down salts.
4. (*a*)	1965	34·74	13·20	3·74	Technical Memorandum submitted to the Narmada Committee.	Envisages construction of a dam 4 miles upstream of Navagam with FRL+490—provides average 29 per cent of double-cropping.

(1)	(2)	(3)	(4)	(5)	(6)	(7)
(*b*)	1965	4·50	2·45	5·45	"Note on the possibilities of reclamation and irrigation of Great Rann of Kutch" submitted to the Committee.	Envisages double cropping to the extent of 70 per cent.
(*c*)	1965	6·57	1·90	2·89	" Note on the water resources of rivers crossed by the Narmada High Level Canal ", submitted to the Committee.	To provide irrigation facilities to areas now under Mahi command.
		45·81	17·55	3·79		

$$\text{Delta} = \frac{\text{million acre feet of water}}{\text{million acres of land irrigated}}$$

Area of land irrigated is the area over which irrigation water is given, irrespective of whether irrigation is perennial or more than one crop has been raised. It is not the cropped area.

4·26 It will be seen that the demands of both Madhya Pradesh and Gujarat States over the Narmada waters have been rising with each successive presentation. This matter has been examined and dealt with by the Committee in Chapter VII.

CHAPTER V

HYDROLOGY

5·1 Narmada is the fifth largest river in India. Yet systematic gauge and discharge observations were started on it only in the year 1947, when the then Central Waterways, Irrigation and Navigation Commission took up investigations for formulating flood control measures and for an assessment of available water resources that could be used for development of irrigation, hydro-power, etc. Prior to that, only some high flood levels appear to have been observed in connection with a bridge project and for flood protection works at Broach during the years 1907 and 1919.

Discharge Observations and Run-off

5·2 The Central Waterways, Irrigation and Navigation Commission opened 11 discharge observation stations on Narmada during the years 1948—1951. These are listed in Table 5·1

TABLE 5·1

Discharge sites set up by CWINC

Sl. No.	Name of station	Name of river	Year of establishing site	Purpose for which station established
1	Manote ..	Narmada	1948	To know discharge for Bilghara Dam site.
2	Bargi ..	Narmada	1948	To know discharge at Bargi Dam site
3	Jamtara Rly. Bridge ..	Narmada	1949	To know discharge below Bargi Dam site (Bargi discontinued).
4	Punasa ..	Narmada	1951	To know discharge for Punasa Hydro-electric Project.
5	Mortakka Rly. Bridge	Narmada	1948	To know discharge for Punasa Hydro-electric Project.
6	Khora Khada ..	Burhner	1949	To know discharge of Burhner river for Ghugri Dam.
7	Mohgaon ..	Burhner	1948	
8	Dhudhi Rly. Bridge ..	Dhudhi River.	1950	For Dhudhi Project
9	Bari ..	Barna	1949	To know discharge of Barna for Bari Irrigation Project.
10	Tawa Dam site ..	Tawa	1949	To know discharge of Tawa for Tawa Irrigation Project.
11	Gardeshwar ..	Narmada	1948	To know discharge for Broach Irrigation Project.

5·3 These stations were confined to important sites on the main river and its tributaries. The work was handed over to the State Governments in 1953. The State Government continued observations at Jamtara, Tawa, Mortakka and Gardeshwar sites, but discontinued them at other places.

Subsequently, the State Governments of Madhya Pradesh and the then Bombay State set up a number of other gauge and discharge sites in order to prepare some schemes for increased food production. A list of Gauge and Discharge sites set up by the State Governments in the Narmada basin is given in Table 5·2 (see also Plate V—1).

TABLE 5·2

Gauge and Discharge sites set up by State Governments in Narmada Basin

Sl. No.	Name of site	Name of river	Nature of observations	Observing Agency	Remarks
			I. Madhya Pradesh		
1	Sankalghat ..	Narmada	Gauge and discharge	Hiran Irrigation Division.	Data available from June, 1956 to date.
2	Hoshangabad ..	,,	,,	Irrigation Division, Narsinghpur.	Data available from July 1963 to date.
3	Dharamrai ..	,,	,,	Khargone Irrigation Division.	Observations started in 1960 by CW &PC. Taken over by M. P. Government in June, 1962.
4	Lawakheri (Kolar Dam).	Kolar	,,	Irrigation Division, Bhopal.	..
5	Surai Dabha ..	,,	,,	,,	Started in June, 1954
6	Sukta Dam site	Sukta	,,	Sukta Irrigation Division.	Started in July, 1954
7	Barbaspur ..	Banjar	,,	..	Observations started in 1956 and continued.
8	Chipaghat ..	Hiran	Gauge	Hiran Irrigation Division	Data available from September, 1955 to March, 1956. Site shifted to Pondi.
9	Pondi ..	,,	Gauge and discharge.	,,	Data available from March, 1956 to date.
10	Dhorda Mohar	Tawa	Gauge	,,	..
11	Chiddgam ..	Ganjal	,,	,,	..
12	Harda Khas ..	Anjal	,,	Irrigation Division, Narsinghpur.	..
13	Mandla ..	Machak	,,	Sukta Irrigation Division.	Set up in June, 1956

Sl. No.	Name of site	Name of river	Nature of observations	Observing agency	Remarks
14	Asapur ..	Agni	Gauge	Khargone Irrigation Division.	Data available from July, 1955.
15	Bhamgarh ..	Chhota Tawa.	,,	,,	Data available from July, 1955.
		II. Gujarat			
1	Broach ..	Narmada	Gauge	Dy. Engineer, N. H. Sub-Division, Broach.	Observation continued from 1887 to date.
2	Rajpipla ..	Karjan	Gauge and discharge	Narmada Irrigation Circle.	Station was set up in 1954
3	Jojwa ..	Orsang	Gauge	Baroda Panchayat Division.	Observations taken on weir
4	Bodeli ..	Orsang	Gauge and discharge	River Gauging Subdivision.	Observations continued from June 1957 to date.
5	Wasna ..	Heran	,,	Baroda Irrigation Divsion.	Observations continued from September 1951 to date.
6	Amadra ..	Unch	,,	River Gauging Subdivison.	Observations continued from June, 1952 to February, 1955.
7	Kikawada ..	Sukhi	,,	,,	Observations continued from June, 1957 to date.

5·4 So far as the main stem of the Narmada river is concerned, there are only three important discharge observation sites, viz., Jamtara (for Bargi), Mortakka (for Punasa) and Gardeshwar (for Navagam).

Jamtara (12 miles below Bargi Dam site)

Catchment Area 6,400 sq. miles

Period		Number of rain-gauge stations in the catchment	Mean annual rainfall (inches)
1948—1962	..	11	57·1
1931—1962	..	8—11	60·2
1915—1962	..	5—11	61·3

5·5 This site is located on the Narmada river at the bridge on the South Eastern Railway line from Balaghat to Jabalpur. Observations are carried out daily. Before the rains, the cross section of the river up to the high banks is taken and areas for different water levels are tabulated. The bridge consists of six openings. Each span is divided into five equal compartments. Thus the whole width of the river is divided into 30 equal compartments for calculating the discharge. The gauge is fixed on one of the piers of the bridge. Velocity is measured by current meter in the centre of each compartment at 0·6 depth. The discharge of each compartment is obtained by the product of area and velocity. The discharges of all the compartments are totalled to give the total discharge. This site is used for discharge measurement only during rainy season. During the dry weather the site is shifted 1,000 ft. downstream, where waterflows through a narrow channel, and observations are made there by current meter.

5·6 The daily discharge data are available from 1948 onwards. The cross section of the gauging site for the monsoon observation is given in Plate V-2. The monthly observed runoff for the years 1948 to 1965 is given in Table 5·3.

TABLE 5·3

Monthly Runoff at Jamtara (below Bargi)

(As observed by current meter)

MAF

Sl. No.	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1.	1948 ..	..	..	..	..	..	..	1·860	3·605	2·304	0·333	0·212	0·086	..
2.	1949 ..	0·055	0·051	0·033	0·010	0·003	0·024	0·599	1·970	1·348	0·616	0·138	0·046	4·893
3.	1950 ..	0·040	0·041	0·052	0·022	0·005	0·021	2·333	3·641	1·108	0·139	0·045	0·040	7·487
4.	1951 ..	0·032	0·020	0·011	0·046	0·007	0·033	0·091	2·123	1·059	0·310	0·047	0·029	3·803
5.	1952 ..	0·014	0·009	0·006	0·003	0·001	0·107	1·868	3·640	1·909	0·208	0·059	0·032	7·856
6.	1953 ..	0·032	0·020	0·007	0·003	0·001	0·001	1·421	2·426	0·996	0·197	0·060	0·033	5·196
7.	1954 ..	0·020	0·009	0·004	0·003	0·001	0·017	1·048	1·783	2·215	0·288	0·073	0·026	5·487
8.	1955 ..	0·022	0·017	0·008	0·003	0·001	0·341	1·130	2·939	3·177	1·159	0·199	0·078	9·074
9.	1956 ..	0·037	0·020	0·010	0·006	0·003	0·146	3·541	5·463	1·331	0·634	0·261	0·086	11·538
10.	1957 ..	0·090	0·038	0·048	0·029	0·007	0·013	1·591	3·261	1·211	0·179	0·055	0·029	6·546
11.	1958 ..	0·017	0·012	0·023	0·007	0·001	0·004	1·866	1·518	1·497	1·056	0·172	0·059	6·232
12.	1959 ..	0·048	0·037	0·011	0·007	0.003	0·002	2·426	3·730	2·637	0·495	0·119	0·057	9·572
13.	1960 ..	0·063	0·029	0·019	0·017	0·005	0·070	1·362	3·498	0·786	0·699	0·201	0·061	6·810
14.	1961 ..	0·045	0·042	0·017	0·005	0·001	0·222	4·762	4·439	4·337	0·863	0·492	0·121	15·346
15.	1962 ..	0·065	0·039	0·027	0·018	0·007	0·071	0·703	1·821	1·509	0·240	0·077	0·278	4·855
16.	1963 ..	0·051	0·019	0·014	0·008	0·008	0·067	0·886	2·505	2·458	0·232	0·098	0·049	6·395
17.	1964 ..	0·031	0·041	0·015	0·005	0·002	0·061	2·499	4·265	1·458	N.A.	N. A.	N. A.	..
18.	1965 ..	0·037	0·021	0·014	0·023	0·003	0·095	N. A.	..	..	..	..	..	..
	Total ..	0·699	0·465	0·319	0·215	0·059	1·295	29·986	52·627	31·340	7·648	2·308	1·110	..
	Mean ..	0·041	0·027	0·019	0·013	0·003	0·076	1·764	3·096	1·844	0·478	0·144	0·694	8·199

Mortakka (37 miles below Punasa Dam site)

Catchment Area 25,942 sq. miles

Period	Number of raingauge stations in the catchment	Mean annual rainfall (Inches)
(1)	(2)	(3)
1948—1962	45—53	50·33
1931—1962	41—53	53·53
1915—1962	29—53	52·86

5·7 This gauging site was established by the CWINC in 1948, and regular discharge observations are being made ever since. It is located on the Narmada river, close to the Bridge on the Western railway meter gauge line from Khandwa to Indore.

5·8 The velocities and gauges are recorded at a section 300 ft. downstream of the railway bridge mentioned above.

The bridge has got 14 spans. Velocity is measured by surface floats which are dropped at the centre of each span and the time taken by them to travel 200 ft., *i. e.*, 100 ft. upstream and 100 ft. downstream of gauging site, is noted. Two or three float readings are taken for each span and the average is taken as the surface velocity for the span. The mean velocity is taken as 0·8 of the surface velocity.

5·9 The areas for each span worked out from the cross section of the gauging site for different water levels at one foot interval are tabulated for ready reference. The table is brought up to date every year after fresh cross section at the gauging site is taken. The total of the discharges observed for different compartments [worked by A × V (mean) for each compartment] gives the total discharge at the site.

5·10 The readings for the velocity are taken once a day. The gauge readings are taken three times a day during non-monsoon months, *i. e.*, November to June, and hourly during monsoon months. Continuous daily data are available from 1948 to date. The cross section of the gauging site is shown in Plate V-3. The monthly observed runoff for the years 1948—1965 (with reduction coefficient 0·8 and 0·85) is given in Table 5·4.

TABLE 5·4

Monthly Runoff at Mortakka (Downstream of Punasa)

(As observed) MAF

Sl. No.	Year	Reduction co-efficient 0·80												Total runoff with coeff. 0·85
		January	February	March	April	May	June	July	August	September	October	November	December	Total	
1.	1948	..	..	..	..	..	..	7·234	10·821	10·646	1·995	1·256	0·612	..	..
2.	1949	0·362	0·253	0·204	0·126	0·089	0·231	3·611	6·462	10·630	3·066	0·964	0·397	26·395	28·045
3.	1950	0·228	0·167	0·209	0·134	0·103	0·120	6·372	8·761	6·430	0·951	0·325	0·268	24·068	25·572
4.	1951	0·255	0·163	0·137	0·254	0·102	0·227	1·438	5·729	3·624	0·937	0·338	0·208	13·412	14·250
5.	1952	0·164	0·117	0·103	0·066	0·049	0·357	3·583	10·441	3·888	0·671	0·280	0·195	19·914	21·159
6.	1953	0·168	0·125	0·104	0·066	0·045	0·058	4·011	11·281	3·411	0·786	0·307	0·225	20·587	21·874
7.	1954	0·160	0·112	0·074	0·056	0·044	0·106	2·650	4·603	12·044	2·136	0·669	0·334	22·988	24·425
8.	1955	0·214	0·147	0·084	0·057	0·044	0·477	2·051	8·608	14·877	5·691	0·946	0·444	33·640	35·743
9.	1956	0·282	0·188	0·136	0·100	0·076	0·738	9·610	11·508	6·194	2·337	1·468	0·541	33·178	35·252
10.	1957	0·467	0·277	0·250	0·239	0·117	0·402	2·615	7·816	4·436	0·750	0·345	0·224	17·938	19·059
11.	1958	0·179	0·130	0·138	0·075	0·056	0·170	3·732	6·294	7·866	3·438	0·974	0·396	23·445	24·910
12.	1959	0·248	0·177	0·130	0·080	0·058	0·132	8·912	13·266	12·671	2·720	0·809	0·414	39·617	42·093
13.	1960	0·421	0·236	0·186	0·145	0·097	0·209	3·516	13·520	2·520	2·060	0·597	0·397	23·904	25·398
14.	1961	0·272	0·209	0·145	0·108	0·081	0·485	8·337	9·812	20·492	5·364	1·144	0·612	47·061	50·002
15.	1962	0·432	0·290	0·237	0·182	0·117	0·086	2·541	4·474	9·887	1·333	0·533	0·620	20·732	22·028
16.	1963	0·295	0·186	0·154	0·099	0·068	0·201	1·525	7·918	7·858	1·059	0·434	0·286	20·083	21·338
17.	1964	0·197	0·145	0·130	0·085	0·065	0·327	6·947	7·574	4·727	1·800	N·A.	N·A.	..	..
18.	1965	0·215	0·124	0·104	0·091	..	..	..	..	..	..	..	..	..	..
	Total	4·559	3·046	2·525	1·963	1·211	4·326	78·685	148·888	142·201	37·094	11·389	6·173	..	..
	Mean	0·268	0·179	0·148	0·115	0·076	0·270	4·629	8·759	8·365	2·182	0·712	0·386	26·089	27·720

Gardeshwar (7 miles below Navagam Dam site)

Catchment Area 34,496 sq. miles

Period		Number of raingauge stations in the catchment	Mean annual rainfall (Inches)
(1)		(2)	(3)
1948—1962	..	57—69	46·04
1931—1962	..	49—69	48·59
1915—1962	..	34—69	47·82

5·11 A gauge discharge site was established by the CWINC in 1948 just below the temple at Gardeshwar about seven miles downstream of the proposed dam site at Navagam. The river at this point is known to have maintained a fairly straight course and a stable section for a long time. Three sets of gauges were erected along the right bank of the river situated 1,000 ft. apart. The gauge observations were taken on all these three gauges thrice a day at 8, 12 and 18 hours. Velocity measurements along five compartments were taken thrice a day by letting down surface floats from a boat plying across the river. The float run off 200 ft. was marked by erecting sighting posts on the banks. The time of travel of surface floats along the five cross sections was observed with the help of these posts. At very high floods exceeding about 10 lakh cusecs, when it was not possible to ply the boat in the river, surface velocity measurements were taken by sighting some floating material or debris. The discharge site was taken over by the State Government in 1953 and observations continued up to 1960.

5·12 In April 1961, a high level bridge was completed across the river along the Eastern State Highway just downstream of the discharge station. From then onwards, the State Government have made use of the bridge for current meter observations. A gauge has been painted on a bridge pier for observing water levels and velocities are observed in a reach downstream by current meter calibrated up to 11·5 ft. per second. At higher velocities, during floods, floats have to be used.

5·13 Just before the monsoon of 1962, a 45 H. P. motor launch was acquired by the Gujarat State for taking discharge measurements during monsoon and for conducting hydrographic surveys of the river channel downstream of the dam in dry months.

5·14 During the monsoon of 1962, hourly observations were taken on the three sets of gauges at Gardeshwar from the 6th July 1962 to the 1st October 1962. Gauge observations were also taken thrice a day at the gauge on the pier of the Akteshwar bridge and also at the gauge set up on the right bank downstream of Akteshwar bridge. From the gauge and velocity measurements taken as above, the discharges were computed. The average surface velocity for the entire cross section of the river was found from compartmental velocities observed and by considering the end compartments as 2/3rd effective. The Mean velocity of the cross section was found by applying a co-efficient of 0·85 to the mean surface velocity.

5·15 Gujarat have stated that the calculations prior to 1961 differed from the above procedure in the following respects :—

(*i*) The travel times for the run of 200 ft. at the various compartments had been averaged instead of velocities as done since 1961.

(*ii*) The end compartments had been considered as half effective instead of two-thirds effective.

(*iii*) A reduction co-efficient of 0·78 for converting the surface velocity into mean velocity had been used instead of 0·85.

5·16 Gujarat State have revised the earlier data from 1948 to 1961 on the basis of the gauge discharge curve developed from the observations in 1962.

The cross section of the gauging site is given in Plate V-4. The observed runoff by months for the period 1948 to 1965 is given in Table 5·5.

TABLE 5·5

Monthly observed Runoff at Gardeshwar (downstream of Navagam)

(with reduction co-efficient 0·85)

MAF

Sl. No.	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1.	1948 ..	..	..	..	..	..	1·191	8·541	13·484	14·815	2·343	1·430	0·762	..
2.	1949 ..	0·424	0·253	0·208	0·138	0·083	0·408	3·964	7·536	14·172	5·023	1·330	0·532	34·071
3.	1950 ..	0·257	0·260	0·231	0·149	0·102	0·109	7·173	10·921	11·539	1·873	0·644	0·400	33·658
4.	1951 ..	0·370	0·188	0·155	0·147	0·104	0·233	2·694	7·206	4·033	1·002	0·368	0·275	16·775
5.	1952 ..	0·199	0·148	0·114	0·068	0·036	0·390	3·504	11·152	4·369	0·815	0·366	0·235	21·396
6.	1953 ..	0·186	0·139	0·101	0·056	0·033	0·510	3·759	12·818	4·020	1·138	0·389	0·277	23·426
7.	1954 ..	0·226	0·110	0·083	0·049	0·032	0·151	3·552	5·324	18·243	1·007	0·151	0·558	29·486
8.	1955 ..	0·386	0·251	0·087	0·065	0·046	0·667	2·445	8·843	18·444	7·095	1·641	0·567	40·537
9.	1956 ..	0·416	0·314	0·220	0·144	0·102	0·881	10·099	14·342	4·349	2·500	1·340	0·500	35·207
10.	1957 ..	0·483	0·326	0·277	0·252	0·121	0·629	2·596	9·390	5·006	1·024	0·452	0·315	20·871
11.	1958 ..	0·256	0·168	0·164	0·094	0·060	0·320	4·209	6·957	10·706	4·236	0·537	0·206	27·913
12.	1959 ..	0·131	0·087	0·063	0·038	0·022	0·058	7·069	16·829	23·776	0·216	1·764	0·885	54·938
13.	1960 ..	0·809	0·547	0·313	0·259	0·203	0·631	3·981	14·690	3·035	5·955	..	..	..
14.	1961 ..	0·219	0·194	0·134	0·127	0·066	0·640	9·284	11·482	28·000	8·000	1·410	0·520	60·126
15.	1962 ..	0·360	0·260	0·190	0·140	0·080	0·080	3·030	5·070	13·110	1·530	0·540	0·560	24·950
16.	1963 ..	0·240	0·160	0·140	0·090	0·070	0·520	1·550	9·605	8·144	1·186	0·487	0·269	22·461
17.	1964 ..	0·266	0·214	0·121	0·094	0·075	0·350	5·441	12·863	5·554	2·308	0·525	0·341	28·152
18.	1965 ..	0·280	0·176	0·121	0·088	0·074	0·137	..	..	..	..	..	..	..
	Total ..	5·508	3·795	2·722	1·998	1·109	7·905	82·891	178·512	191·315	47·251	13·374	7·202	..
	Mean ..	0·324	0·223	0·160	0·118	0·065	0·439	4·876	10·501	11·254	2·775	0·83[illegible]	0·450	32·022

5·17 Since the data available by discharge observations is only for a limited period of 15 years or so, the Committee requested the CW & PC to work out a runoff series, based on the rainfall records available for the Narmada basin, after working out a rainfall runoff relationship for the observed data for the period 1948 onwards. The CW & PC, in th Hydrological Directorate, have carried out these studies and established a rainfall runoff relationship based on the run-off data from 1948 to 1962. This has been further discussed in para. 5·27 of this Chapter.

Raingauge networks and rainfall

5·18 According to I. M. D. records there were 10 raingauges in 1867 in the entire Narmada basin. In 1891, the year from which published rainfall data are available in the I. M. D. rainfall volumes, the number of raingauges functioning was 21. From 1891 to 1961, the steady growth of raingauge network in the basin is shown in Plate V-5. The number above Gardeshwar for which printed records are available is 69 at present. The distribution of raingauges over the catchments between principal project sites for the years 1891, 1911, 1931, 1951 and 1961 is given in Table 5·6.

TABLE 5·6

Density of Raingauge stations in Narmada basin

Year	Up to Bargi (5,620 sq. miles)		Between Bargi and Punasa (18,180 sq. miles)		Between Punasa and Barwaha (1,250 sq. miles)		Between Barwaha and Hiranphal (6,359 sq. miles)		Between Hiranphal and Navagam (2,381 sq. miles)		Total catchment up to Navagam (33,970 sq. miles)	
	Total rain-gauges	Area per rain-gauge	Total rain-gauges	Area per rain-gauge	Total rain-gauges	Area per rain-gauge	Total rain-gauges	Area per rain-gauge	Total rain-gauges	Area per rain-gauge	Total rain-gauges	Area per rain-gauge
1891 ..	4	1,405	15	1212	..	..	1	6,359	1	2,381	21	1,609
1911 ..	5	1,124	22	826	1	1,250	3	2,120	1	2,381	32	1,056
1931 ..	8	703	30	606	1	1,250	8	795	1	2,381	48	704
1951 ..	11	511	34	535	2	625	10	636	2	1,191	59	573
1961 ..	11	511	37	491	3	417	14	454	4	595	69	490

5·19 From the above table it is apparent that in the early years of records, the density of raingauges was not adequate to fully represent the catchment. However, from 1931 onwards, the density has improved in the various sub-catchments excepting the small reaches between Punasa-Barwaha and Hiranphal-Navagam, where the improvement has been only in recent years since 1951.

5·20 In the preparation of table 5·6, data of *non-publishing* raingauge stations maintained by Departments other than I. M. D. have been excluded, as these stations do not generally conform to I. M. D. standards ; moreover their data are not available continuously.

5·21 In order to study the effect of improvement in the raingauge network on catchment rainfall, the average rainfall values for each of the five principal project sites for different years during the period 1948 to 1960 were computed by taking into consideration the raingauge network existing during individual years of this period. These values were then compared with the rainfall values of these very years (1948 to 1960) obtained by using only those raingauges which existed during the years 1891, 1911 and 1931. The results of this study are given in Table 5·7.

TABLE 5·7

Mean annual rainfall of Narmada catchment at different sites

(Inches)

Year	Up to Bargi CA5620 sq. miles				Up to Punasa CA23800 sq. miles				Up to Barwaha CA25050 sq. miles.				Up to Hiranphal CA31409 sq. miles.				Up to Navagam CA33970 sq. miles.			
	1891 Stns.	1911 Stns.	1931 Stns.	Actual *	1891 Stns.	1911 Stns.	1931 Stns.	Actual *	1891 Stns.	1911 Stns.	1931 Stns.	Actual *	1891 Stns.	1911 Stns.	1931 Stns.	Actual *	1891 Stns.	1911 Stns.	1931 Stns.	Actual *
	4	5	8		19	27	38		19	28	39		20	31	47		21	32	48	
1948 ..	66·19	65·19	61·44	62·94	65·94	65·63	61·10	60·52	65·94	64·75	60·69	59·82	65·94	62·48	57·22	56·16	65·94	61·37	56·64	55·51
1949 ..	58·88	58·88	58·86	60·33	54·98	55·72	53·96	54·72	54·98	55·08	53·58	53·86	54·98	52·66	49·64	51·07	54·98	52·17	49·39	47·78
1950 ..	62·70	62·70	59·61	60·12	48·55	47·67	48·06	50·43	48·55	46·94	47·57	48·57	48·55	44·99	44·18	45·29	48·55	45·30	44·39	43·96
1951 ..	54·87	54·87	49·84	51·15	40·49	39·61	39·63	39·31	40·49	38·96	39·24	39·08	40·49	37·56	35·96	36·00	40·49	37·22	35·78	34·67
1952 ..	55·32	55·32	55·27	54·84	42·15	40·34	42·37	42·79	42·15	39·59	39·54	40·30	42·15	37·50	35·46	36·85	42·15	37·04	35·22	35·72
1953 ..	44·20	44·20	47·73	50·21	45·03	45·50	44·55	44·43	45·03	44·85	44·14	44·61	45·03	43·69	44·43	41·21	45·03	42·96	41·96	41·13
1954 ..	47·21	47·21	48·73	47·54	51·70	52·08	50·67	59·47	51·70	51·83	50·54	49·44	51·70	51·55	49·03	48·11	51·70	51·55	49·09	48·24
1955 ..	66·61	66·61	65·22	66·35	60·96	61·88	59·89	61·64	60·96	60·67	59·13	61·11	60·96	58·46	54·66	55·76	60·96	57·69	54·27	54·82
1956 ..	58·68	58·68	61·30	64·23	54·67	53·32	54·01	56·85	54·76	52·26	53·27	55·44	54·76	50·36	49·18	48·27	54·76	50·15	49·07	49·34
1957 ..	50·40	50·40	48·83	54·17	44·73	44·88	42·15	42·99	44·73	44·33	41·87	41·98	44·73	42·23	38·99	39·22	44·73	41·76	38·78	39·00
1958 ..	55·07	55·07	53·30	53·85	47·90	49·18	49·44	47·89	47·90	49·11	49·39	47·72	47·90	48·39	47·40	46·34	47·90	48·37	47·41	45·55
1959 ..	62·50	62·50	60·44	60·83	61·14	61·26	58·99	57·07	61·14	60·34	58·44	56·50	61·14	59·84	57·42	54·85	61·14	58·90	56·89	55·07
1960 ..	59·70	59·70	59·08	59·28	46·92	46·78	48·24	46·76	46·92	45·74	47·52	45·71	46·92	44·96	44·07	42·70	46·92	43·82	43·68	42·72

* As per number of raingauge stations in the particular year

5·22 It may be seen from this table that there is no significant difference between rainfall values obtained with 1931 raingauges and those obtained with raingauges existing during the period 1948 to 1960. As indicated by this study, the construction of runoff series could be considered adequate if extended backward only up to 1931. This provides a long enough series for yield analysis and has the merit of not appreciably vitiating the reliability of the series by inadequacy and mal-distribution of raingauges which existed in the years prior to 1931.

5·23 For computing the rainfall up to different sites, arithmetical average method has been used. As a check, arithmetical average values for selected years for three major sites, for which discharge observations are available, have been compared with the isohyetal values and the results are shown in Table 5·8.

TABLE 5·8

Annual rainfall of Narmada Catchment

Year	Up to Bargi		Up to Barwaha		Up to Gardeshwar (Navagam)	
	Isohyetal	Simple average	Isohyetal	Simple average	Isohyetal	Simple average
1891 ..	62·24	56·59	61·17	64·67	52·97	52·99
1911 ..	54·27	52·62	42·66	44·25	36·18	36·29
1931 ..	64·78	66·02	61·95	61·61	57·46	59·98
1950 ..	61·35	60·12	47·65	48·57	43·99	43·96
1951 ..	49·88	51·15	38·21	39·08	34·74	34·67
1952 ..	53·63	54·85	40·31	41·30	34·89	35·72
1961 ..	81·85	84·57	71·50	73·58	64·09	66·88

5·24 It will be seen from this table that isohyetal and arithmetical average values compared well for all the sites except for the year 1891. Studies have also indicated that about 87 per cent of the total rainfall is during the four monsoon months, viz., June to September. Table 5·9 gives the rainfall during the monsoon

months as compared to the annual rainfall at the different sites for the years 1947 to 1960.

TABLE 5·9

Monsoon rainfall of Narmada Catchment

Year	Up to Bargi		Up to Barwaha		Up to Gardeshwar (Navagam)	
	Annual	Monsoon	Annual	Monsoon	Annual	Monsoon
1947 ..	63·39	55·51	59·47	51·38	52·37	45·89
1948 ..	62·24	49·60	60·52	52·36	55·51	48·05
1949 ..	60·33	49·31	54·72	46·46	47·78	42·66
1950 ..	60·12	53·33	50·43	43·65	43·96	41·11
1951 ..	51·15	42·66	39·31	33·45	34·67	34·27
1952 ..	54·84	54·08	42·79	39·36	35·72	34·19
1953 ..	50·21	44·13	44·43	37·12	41·13	34·19
1954 ..	47·54	45·53	49·47	47·87	48·24	46·40
1955 ..	66·35	57·12	61·64	50·16	54·83	44·88
1956 ..	64·23	58·56	56·85	47·57	49·34	42·58
1957 ..	54·17	44·74	42·99	36·81	39·00	34·12
1958 ..	53·85	44·60	47·89	42·97	45·55	41·39
1959 ..	60·83	56·02	57·07	53·39	55·07	..
1960 ..	59·28	48·65	46·74	40·84	42·72	36·46
Total ..	809·53	703·84	714·32	623·39	645·89	526·19
Average ..	57·82	50·27	51·02	44·53	46·13	40·48
Percentage of annual.		87%		87%		87·5%

5·25 Subsequently during discussions, the representative of Madhya Pradesh Government pointed out that the runoff series for the period 1931 to 1962 did not cover some important drought cycles (years of low rainfall) and the dependable flows worked out on that basis would not be very accurate.

The Committee, therefore, decided that the runoff series should be projected back to the year 1915 to give a fair presentation of the rainfall runoff cycle.

Zonal Analysis

5·26 It was also decided at this stage that the runoff studies made by the C,W.&P.C. should be recast on the basis of a zonal analysis dividing the Narmada basin into 4 zones as under—

(1) Catchment area up to Jamtara ;

(2) Catchment area of Tawa river up to Railway Bridge site ;

(3) Area between Jamtara and Mortakka excluding Tawa catchment up to Bridge site ; and

(4) Area between Mortakka and Gardeshwar.

5·27 The C.W. & P.C. have carried out these further studies on zonal basis and have worked out fresh linear relationships. These are indicated in Plates V-6 to V-9. The relationships are:—

(*i*)	For catchment area up to Jamtara ..	R=0·28 P—8·827
(*ii*)	For catchment area of Tawa river up to Tawa Railway Bridge.	R=0·13 P+3·68
(*iii*)	For area between Jamtara and Mortakka excluding Tawa.	R=0·61 P—11·21
(*iv*)	For area between Mortakka and Gardeshwar	R=0·28 P—4·16

Where R is the runoff in MAF and P is the rainfall in inches.

Based on these, the runoff series for the years 1915—1962 at the important project sites have been arrived at and are indicated in Table 5·10. The figures of monthly runoff for this period for Hiranphal and Navagam Dam sites are given in Tables XII—2 (A) and XII—2 (B) of Annexure XII—2 of Chapter XII.

TABLE 5·10

Runoff of Narmada at various Project sites based on zonal studies (using coefficient for reduction of surface velocity as 0·85)

Sl. No.	Year	Annual runoff of Narmada in MAF at								
		Jamtara	Tawa	Jamtara to Punasa	Punasa to Gardeshwar	Total Navagam	Punasa	Barwaha (Mortakka)	Hiranphal	Punasa to Hiranphal
1	1915 ..	11·53	3·74	17·55	6·59	39·41	32·82	35·31	37·93	5·11
2	1916 ..	9·95	6·05	20·47	6·22	44·69	36·47	39·38	42·77	6·30
3	1917 ..	13·20	4·82	21·71	9·72	49·45	39·73	42·81	47·05	7·32
4	1918 ..	6·04	0·33	6·74	0·96	14·07	13·11	14·07	14·07	0·96
5	1919 ..	14·78	2·05	22·71	11·55	51·09	39·54	42·76	48·08	8·54
6	1920 ..	5·08	1·14	8·52	5·74	20·48	14·74	15·95	18·85	4·11
7	1921 ..	6·59	2·70	12·74	6·79	28·82	22·03	23·84	27·02	4·99
8	1922 ..	7·90	2·36	12·82	4·60	27·68	23·08	24·90	26·68	3·60
9	1923 ..	12·74	4·47	18·99	6·22	42·42	36·20	38·89	41·15	4·95
10	1924 ..	7·72	3·29	15·00	7·55	33·56	26·01	29·14	31·60	5·59
11	1925 ..	8·50	2·03	11·73	3·14	25·40	22·26	23·93	24·87	2·61
12	1926 ..	17·54	3·88	17·70	5·30	44·42	39·12	41·63	43·41	4·29
13	1927 ..	6·64	2·09	13·58	7·31	29·62	22·31	24·24	27·68	5·37
14	1928 ..	4·91	3·61	15·82	6·58	30·92	24·34	26·58	29·35	5·01
15	1929 ..	8·14	2·37	13·60	3·98	28·09	24·11	26·04	27·35	3·24
16	1930 ..	8·21	3·17	15·30	7·49	34·17	26·68	28·85	32·25	5·57
17	1931 ..	9·60	5·05	20·78	10·47	45·90	34·43	38·38	43·19	8·76
18	1932 ..	6·88	4·43	16·02	7·63	34·96	27·38	29·60	33·03	5·70
19	1933 ..	11·04	6·12	19·07	11·30	47·53	36·23	38·94	44·43	8·20
20	1934 ..	9·58	5·14	21·15	7·90	43·77	35·87	38·87	42·00	6·13
21	1935 ..	7·24	3·58	13·95	4·55	29·32	24·77	26·75	28·39	3·62
22	1936 ..	11·78	2·96	18·41	6·15	39·30	33·15	35·76	38·02	4·87

23	1937	..	9·63	5·11	19·74	6·93	41·41	34·48	37·28	39·92	5·44
24	1938	..	10·99	3·71	18·69	7·64	41·03	33·39	36·04	39·23	5·84
25	1939	..	8·83	4·45	15·41	4·58	33·27	28·69	30·88	32·41	3·72
26	1940	..	6·78	4·78	18·87	7·75	38·18	30·43	33·11	36·35	5·92
27	1941	..	1·06	1·83	9·12	3·94	15·95	12·01	13·31	15·00	2·99
28	1942	..	10·51	5·56	20·84	9·05	45·96	36·91	39·87	43·76	6·85
29	1943	..	11·08	4·55	17·50	6·89	40·02	33·13	35·61	38·43	5·30
30	1944	..	12·11	7·83	27·35	13·55	60·84	47·29	51·17	57·35	10·06
31	1945	..	8·80	3·74	17·32	7·58	37·44	29·36	32·32	35·59	5·73
32	1946	..	10·59	3·71	19·83	10·27	44·40	34·13	36·95	41·71	7·58
33	1947	..	9·14	6·85	18·21	6·74	40·94	34·20	36·79	39·44	5·24
34	1948	..	8·41	5·78	21·03	8·32	43·54	35·22	38·21	41·62	6·40
35	1949	..	8·15	3·67	16·03	6·77	34·62	27·85	30·13	33·00	5·15
36	1950	..	8·30	2·48	12·97	7·04	30·79	23·75	25·59	28·91	5·16
37	1951	..	5·57	1·63	8·04	3·08	18·32	15·24	16·38	17·62	2·38
38	1952	..	6·53	1·12	9·19	2·27	19·11	16·84	18·14	18·76	1·92
39	1953	..	4·83	1·94	12·00	5·20	23·97	18·77	20·47	22·71	3·94
40	1954	..	4·16	3·00	17·46	9·88	34·50	24·62	27·10	31·83	7·21
41	1955	..	9·66	4·52	21·32	8·43	42·93	34·50	37·39	40·93	6·43
42	1956	..	9·44	3·58	17·44	8·15	38·61	30·46	32·93	36·56	6·10
43	1957	..	5·55	2·36	10·20	4·54	22·65	18·11	19·56	21·53	3·42
44	1958	..	6·85	2·87	15·02	9·12	33·86	24·74	26·87	31·34	6·60
45	1959	..	8·51	4·41	19·60	12·23	44·84	32·61	35·40	41·43	8·82
46	1960	..	7·82	1·63	13·84	5·86	28·15	23·29	25·25	27·10	3·81
47	1961	..	14·39	5·98	26·43	10·81	57·61	46·80	50·55	55·06	8·26
48	1962	..	5·25	3·14	12·96	5·97	27·32	21·35	23·19	25·83	4·48
	Total	..	418·53	175·41	790·86	342·33	1,725·33	1,383·00	1,496·11	1,642·59	259·59
	Average	..	8·72	3·65	16·48	7·13	35·94	28·80	31·17	34·22	5·41

5·28 Based on the runoff series indicated above, Table 5·11 is prepared showing the yield at various sites with 50 per cent, 75 per cent and 90 per cent dependability : —

TABLE 5·11

Runoff at various sites for different dependabilities

Percentage dependability	Yeild in MAF					
	Jamtara	Tawa	Punasa	Barwaha	Hiranphal	Navagam
50 per cent ..	8·72	3·65	28·83	31·17	34·22	35·94
75 per cent ..	6·68	2·57	23·23	25·14	27·57	28·92
90 per cent ..	4·84	1·59	18·18	19·72	21·59	22·59

Reduction Coefficient

5·29 During discussions a question arose about the " Reduction Coefficient " to be adopted for converting " Surface Velocity " to " Mean Velocity ". At Mortakka a coefficient of 0·8 was being applied for reducing surface velocity to mean velocity. At Gardeshwar a coefficient of 0·78 was being used. As already stated (para. 5·16), from 1961 onwards Gujarat started observations by current meter and, based on their experience and experiments carried over a period of 3 months, suggested a coefficient of 0·85 in the data collected prior to 1960.

5·30 Normally, the velocity observations by current meter are the most reliable; but at many sites surface velocity is being observed by floats because it is simple and cheap. From a practical point of view, measurement by floats is sometimes unavoidable, particularly so where the river is flashy or in high floods. In such cases, it becomes necessary to obtain the mean velocity by applying a suitable coefficient to the surface velocity obtained from floats.

5·31 At the request of the Committee, the C. W. & P. C. carried out a detailed study of this question. Their note is at Annexure V-I. From this it can be concluded that adoption of a reduction coefficient of 0·85 is quite sound and scientific. The observed data have been amended with this coefficient before working out the statistical relationship on zonal basis.

Comments of Madhya Pradesh

5·32 Madhya Pradesh in their comments have stated that the extent of rainfall data utilised by the C. W. &. P. C. is not very satisfactory as some of the raingauge stations were set up for the first time in 1951, 1953, 1954, 1955, 1961 and 1962, and data for certain individual years were not available. They have also mentioned that there are quite a number of other raingauge stations within the Narmada basin, data from which have not been made use of by the C. W. &. P. C. Out of 143 such raingauge stations, only 10 are reported to be I. M. D. stations while the rest are non-I. M. D. stations maintained by Railways, Forest Department and other agencies.

5·33 Madhya Pradesh have further stated that there are other raingauge stations—96 in number—adjoining the Narmada basin, data from which could be profitably utilised for working out the rainfall pattern in the catchment.

5·34 Commenting on the preparation of the rainfall series from 1931 to 1962, Madhya Pradesh have said that this excludes two consecutive low rainfall periods of twelve years and six years (1900—1911 and 1894—1899), which were the worst known droughts in the Narmada basin. They have, therefore, concluded that the results obtained after excluding these cannot be representative. They have also commented that the distribution of raingauge stations is not uniform in the Narmada basin, and, therefore, the relationships developed between the annual rainfall and the annual runoff, taking arithmetical averages, cannot be said to represent the true conditions of runoff in a year ; particularly so, when in different years, data for different number of stations have been used. According to them, the best method would be to prepare isohyetals from rainfall records during July—October every year from 1948 to 1962, then make an attempt to discover the relationship between the weighted average rainfall during the four months July to October in each year with the annual inflow from July to the following June from each sub-catchment, viz :—

(1) Above Jamtara ;

(2) Above Bagra (Tawa) ;

(3) Between Jamtara, Bagra (Tawa) and Mortakka ; and

(4) Between Mortakka and Gardeshwar.

5·35 Based on these studies, they have said that if a good and reasonable relationship could be developed, it could be made use of by applying it to corresponding weighted rainfall in the four sub-catchments in all the earlier years up to 1891. Of course, Madhya Pradesh recognise that such a study would take a long time and the preparation of a Master Plan cannot be held up on that score. They concede that there is little option but to prepare the Master Plan on the basis of available data. They have, therefore, suggested that only the available observed flow data should be made use of in the preparation of such a Master Plan. This, according to them, represents neither a high rainfall cycle nor a low one.

5·36. So far as the reduction coefficient is concerned, they have no objection to accepting the coefficient of 0·85 for converting surface velocity to mean velocity.

Comments of Gujarat

5·37 Gujarat, while commenting on the hydrological studies of the C. W. & P. C., have remarked that the reduction coefficient of 0·885 should be adopted instead of 0·8 for converting surface velocity to mean velocity. They have mentioned that the references quoted by the C. W. & P. C. about reduction coefficient fully corroborate the adoption of a higher reduction factor. If this is accepted, the series would have to be recast accordingly. (The Committee, however, consider that a coefficient of 0·85 should be adopted for the present studies.)

5·38 Gujarat have further stated that instead of developing separate formulae for different zones, it might, perhaps , be advisable and practicable to develop a single formula based on the rainfall runoff relationship for the entire catchment above Gardeshwar. This would, according to them, obviate the effect of mal-distribution of raingauge stations in different parts of the catchment.

5·39 Gujarat have agreed that the runoff series should be from 1931 onwards only, considering the density and mal-distribution of raingauge stations prior to 1931. Subsequently, when the revised note of the C. W. &. P. C. on zonal basis was circulated and the total availability worked out by the integration of runoff of different zones, they have again drawn the attention of the Committee to the fact that observational errors at successive sites may have a cumulative effect on the overall picture of the river flow as against the error arising out of a single observation at the tail end of the river. They have mentioned that the statistical fit of the equations on the basis of considering the entire catchment is better and more accurate as against the zonal studies carried out by the C. W. &. P. C. According to Gujarat, the zonal method is not rational since it ignores, in part, the observed data at the lower gauge sites.

Committee's views

5·40 As already indicated under para. 5·36 above, the Committee consider that a coefficient of 0·85 should be adopted for converting surface velocity to mean velocity.

5·41 The Committee feel that it is not correct to plan the basin development on the basis of observed data for 15 years only. A satisfactory statistical relationship has been established between rainfall and runoff for this period of 15 years, which according to accepted and scientific practice and procedure, can be projected to series of years where rainfall data is available but no discharge data, thus enabling wider coverage in point of years and, therefore, giving more representative results. Going back beyond 1915, when the raingauge stations were very few and ill-distributed, would lead to an incorrect appraisal of the Narmada water potential.

The Committee, therefore, decided that runoff series of the Narmada for the period 1915—1962 should be prepared on the basis of rainfall runoff relationship derived from the observed data of 15 years.

5·42 Gujarat's argument that zonal studies do not lead to correct results is also not scientific. It is an accepted practice all over the world to study rainfall runoff patterns on zonal basis. The zonal studies take into account the rainfall distribution within the zone more precisely than would be possible by taking the entire catchment as one unit. Plate V-1 shows the normal isohyetals of the Narmada basin. It can be seen from this that there is considerable variation in the rainfall of different zones.

5·43 The Committee suggest that more discharge sites be set up in the basin and also that the number of raingauge stations of Indian Meteorological Department standard, especially in the free catchment below Punasa, should be increased. Presently there are only 4 sites, namely, Jamtara, Mortakka and Gardeshwar on the main Narmada and one on the Tawa where regular discharge observations are being carried out since 1949. This number is utterly inadequate for a vast catchment of 38,000 square miles of the Narmada.

ANNEXURE V-I

NOTE ON THE REDUCTION COEFFICIENT FOR CONVERTING SURFACE VELOCITY TO MEAN VELOCITY BY CENTRAL WATER AND POWER COMMISSION

1. Introduction

Gauge discharge observations on the Narmada River are being carried out at Mortakka and Gardeshwar since 1948. At Mortakka the velocity of flow was being recorded by surface floats and a coefficient of 0·8 was being applied for reducing surface velocity to mean velocity. At Gardeshwar also velocity observations were being carried out by surface floats and a reduction coefficient of 0·78 was being used to obtain the mean velocity. From 1961 onwards the Gujarat Engineers started observations by current meter and based on their experience and experiments extending over a period of three months suggested a coefficient of 0·85 for converting surface velocity to mean velocity in the data collected prior to 1960.

During the deliberations of the Narmada Water Resources Development Committee in December 1964 it was decided that the Directorate of Hydrology and Statistics of the C. W. &. P. C. should examine all available literature on the subject and submit a note to the Committee, before a final decision could be taken on the suitable coefficient to be adopted for observations on the Narmada.

2. Reduction Coefficient

Normally, the velocity observations by current meter are the most reliable. But at many sites surface velocity is being observed by floats because it is simple and cheap. From a practical point of view, measurement by floats is sometimes unavoidable, particularly so where the river is flashly or in high floods. In such cases it becomes necessary to obtain the mean velocity by applying a suitable coefficient to the surface velocity obtained from floats.

The choice of the appropriate coefficient, otherwise called the reduction coefficient, depends upon the nature of the site and the flow conditions of the river. It varies from gauge site to gauge site. Hence the most appropriate way of fixing the coefficient for a site is to carry out a series of test experiments for different gauges comparing the surface velocity with the mean velocity. The mean velocity can be determined from the velocity distribution gauge along verticals, or by measuring mean velocity by one point, two point or three point methods.

In the absence of actual experimentation for expediency one may choose coefficients as experienced in similar rivers elsewhere both in India and outside.

The past literature on this subject contains two approaches viz. (*i*) development of empirical formula based on studies; (*ii*) factors derived from experimental results. In the following paragraphs a short survey of the past findings is given under the two categories.

3. Empirical Formulae

(*i*) One of the empirical formulae relating the reduction coefficient with surface velocity is evolved by Prony (1) which is adoptable for relatively narrow deep and vertical side channels. This is given as

$$f \text{ (reduction coefficient)} = \frac{Vcs + 7{\cdot}78}{Vcs + 10{\cdot}35};$$

where Vcs is the central surface velocity. For ordinary ranges of surface velocity, f varies from 0·77 to 0·87.

Von Wagner (1) has advanced a different formula given by $f = {\cdot}705 + .01\ Vs$ where Vs is the maximum surface velocity.

For ordinary ranges of velocities, the value of f varies from 0·71 to 0·81. This formula has been considered suitable for natural channels.

From a series of experimental observations on a number of streams, a general formula in the form $f = \frac{C}{C + 25{\cdot}4}$ where C is the Chezy's coefficient has been suggested by Bazin (2). On the

basis of the above formula, the value of f for different values of R the hydraulic mean depth for earth channels under ordinary conditions has been worked out as under:—

R (H.M.D.) in ft.	Value of f	R (H.M.D.) in ft.	Value of f
1·0	0·649	8·0	0·772
2·0	0·699	10·0	0·781
3·0	0·725	15·0	0·794
4·0	0·740	20·0	0·803
5·0	0·752	30·0	0·613
6·0	0·759	50·0	0·824

Experimental findings

The Irrigation Research Institute, Roorkee, carried out actual observations of Betwa river at the Railway Bridge site (3) about 7,500 ft. below Matatila Dam where the river has a width of about 1,450 ft. and the bed consists of uneven rock. They found the following relationship between the velocity at 0·6 depth (mean velocity) and the surface velocity (Vs.)

$$V._{6d} = 0{\cdot}894\ Vs + 0{\cdot}357$$

According to this relation, the value of the reduction coefficient has a minimum value of 0·894.

In the early days of water measurements in the Canal in Massachusetts, U. S. A. (1) velocities of surface floats in the middle of the stream were observed which were converted into mean velocities by coefficients varying from 0·814 to 0·847.

The U. S. Dept. of the Interior Bureau of Reclamation (4) suggest that for regular channels flowing in a straight course under favourable conditions, the mean velocity in the channel is approximately 0·85 times the surface velocity. It is also pointed out that this value is an average of many observations and for any particular channel, it may be as low as 0·80 or as high as 0·95.

According to Herbert Addison (5) Professor of Hydraulics at the Fuad I University of Egypt the ratio of the mean velocity over a vertical to the surface float velocity increases with the water depth and diminishes as the roughness of the bed increases. For quick emergency gauging, a value of 0·84 has been suggested for adoption.

The following table shows a portion of the results obtained by the U. S. Geological Survey from measurements made on certain rivers in New York, Virginia, Tennessee, North and South Carolina. (1)

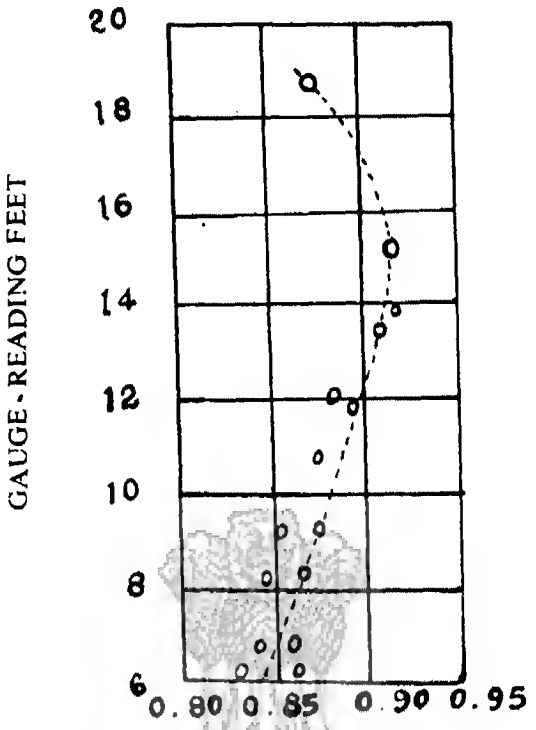
River		Approximate width in ft.	Range of depth in ft.	Coeff. for reducing to mean velocity in any vertical, the velocity observed at top
James Va	..	850	3·0—4·4	0·88
Saluda S.C.	..	800	3·0—8·5	0·82
Little Tennesse NC	..	660	3·6—6·0	0·83
Dan N. C.	..	600	1·4—3·7	0·86
Broad S. C.	..	500	5·0—8·9	0·89
Yadkin S. C.	..	450	4·0—11·3	0·81
Staunton N. C.	..	400	2·0—6·0	0·95
Wateree S. C.	..	300	12·3—17·7	0·90
Nolichuky Tenn.	..	300	1·6—5·1	0·80
Catawba N. C.	..	200	1·8—5·0	0·82
Catawba N. C.	..	200	6·3—7·0	0·88
Appomaton Va	..	150	2·5—4·9	0·81
Yadkin N. C.	..	160	2·7—6·3	0·91
Esopus Creek N.Y.	..	100	2·0—14·0	0·88
Roundout Creek NY.	..	100	4·0—8·0	0·84
Castskill Creek NY.	..	90	2·0—7·0	0·83
Reddie N. C.	..	85	1·7—2·5	0·83

According to Hoyt and Grover, (6) the coefficients to reduce measured surface velocity to mean velocity varies between 0·78 and 0·98, depending upon the depth of the stream and the magnitude of the velocity. The deeper the stream and the greater the velocity, the larger is the coefficient. For average stream conditions a coefficient of about ·9 will give fairly accurate results. According to them, a coefficient between ·90 and ·95 should be used in flood conditions.

The following is the statement giving a summary of the vertical velocity curves in open channels in some of the American streams.(6)

Stream	Range of depth—ft.	Range of velocities	Coeff. for reducing to mean velocity
			Top
Ohio ..	5·3—20·8	0·92—4·43	0·93
Mongahela ..	10·9—17·5	0·74—1·13	0·85
St. Mary ..	2·7—3·9	3·78—6·32	0·88
Jafferson ..	2·7—5·7	1·78—3·45	0·84
Yellowstone ..	4·3—8·5	2·42—3·79	0·89
Shoshone ..	4·3—7·3	4·93—8·45	0·87
Yampa ..	4·2—5·2	7·13—8·42	0·83
Grani ..	9·2—27·5	1·11—4·02	0·93
Gunnison ..	4·9—10·4	1·63—9·59	0·92
Susquehanna ..	5·0—36·0	1·40 —9·70	0·90
Little Tennesse ..	2·7—6·0	3·84—7·45	0·83
Saluda ..	3·0—8·5	1·76 -2·01	0·82
South Fork Holsbon ..	1·9—4·1	1·08—6·77	0·80
Nolichucky ..	1·6—5·1	0·49—2·69	0·80
Mean of 910 curves	..	..	0·85
Highest ..	36·0	9·70	0·95
Lowest ..	1·1	0·18	0·78
Shallow streams with rough beds			
St. Mary ..	1·8—4·2	2·60—6·36	0·86
Swift current Creek ..	1·6—3·2	3·28—6·81	0·87
South Fork Shoshone ..	1·8—3·6	3·61—6·79	0·82
Tieton ..	1·8—4·5	4·42—8·04	0·80
Wallowa ..	2·2—2·9	4·16—4·93	0·78
Mean of 219 curves ..	..	..	0·84
Highest ..	4·5	8·04	0·89
Lowest ..	1·6	1·43	0·78

In Fig. 1 below, is also shown the variation of float coefficient with depth as observed on the river Severn (1921—36) in the U. K. (7)



VARIATIONS FLOAT-COEFFICIENT WITH DEPTH

As could be expected, the coefficients increases with depth. In this case, there is also evidence that the reduction occurs in the coefficient when the discharge exceeds 10,000 cusecs (corresponding to gauge 15 ft.) and flooding commences as indicated by the dotted points.

Numerous observations of vertical velocity curves in the river Indus at Sukkur have been made by the Indus River Commission as part of their investigation (8). The following table gives the coefficients obtained as an average of a number of observations along the vertical for different depths.

Depth of water	No. of tests	Coefficient
8	113	·820
9	124	·818
10	187	..
11	153	·849
12	222	·836
13	132	·832
14	160	·837

Depth of water	No. of tests	Coefficient
15	128	·846
16	139	·851
17	79	·844
18	85	·852
19	45	·846
20	63	·830
21	45	·840
22	38	·835
23	22	·871
24	25	·842
25	25	·841
26	12	·819
27	10	·856
28	6	·862
29	4	·844
30	35	·856
All	1852	·835

Harlacher (8) has found the coefficient varying from 0·83 to 0·88 in his observations on the Danube and Bohemian rivers and suggests 0·85 for general use.

Ballasis "Hydraulics" quotes a small number of data and gives a table suggesting values for the coefficient for different depths and different rugoisity values (9). For channels for which Kutter's N=0·025 and 0 030, these values up to a depth of 20 ft. are extracted below:—

Depth	Reduction Coefficien	
	N=·025	N=·030
1·0	0·82	0·78
2·0	0·86	0·80
5·0	0·89	0·85
10·0	0·90	0·86
15·0	0·91	0·87
20·0	0·92	0·88

According to Grunskey, (9) the value of the reduction co-efficient depends only upon the ratio of the width of stream (W) to the mean depth (D) as indicated below:—

W/D	Co-efficient
5	1·0
20	0·91
50	0·85
100	0·82

Observations on Hemavathi river in the Mysore State (9) with fairly soft bed and vertical banks indicate that the reduction co-efficient varies from 0·85 to 0·88 ; on the other hand, the co-efficient used for the river Cauvery at Chinchinkatta (9) with a rocky bed and sloping banks, ranges between 0·77 and 0·79.

According to the Technical circular No. 2 (1955) of the Government of Iraq, (10) the discharge ovservations were made by measuring half depth velocities by current meter and applying a co-efficient of 0·96 for getting the mean velocities.

The following are the extracts from the book, Stream-gauging- Part-II-measurement of discharges on streams by Hiranandani and Chitale (11) published by Central Water & Power Research Station. "The mean velocity over the vertical is then arrived at by using a conversion factor. The value of this factor , called the Reduction Co-efficient, is however not constant. Experiments on different rivers indicate this value to vary between 0·79 to 0·91 . In Holland this value has been found to be 0·86 in sandy beds. In China, it is adopted as 0·9 for large and deep rivers and 0·8 for small and shallow rivers. In Punjab, a large number of observations gave the value as 0·89. This value of 0·89 is in general use in other parts of India as well. Since the ratio of surface to the average velocity cannot be expected to be constant in different streams and at different flood stages, it is inadvisable, to adopt any reduction factor blindly. It is always desirable that the reduction factor be based on actual field observations made by a current meter on a particular stream."

The manual of Instructions (12) for discharge observations issued by the C. W. P. C. Field Investigation Administration (Flood Wing) suggests the co-efficient to be employed for converting surface velocity into mean velocity to be taken as 0·89.

On the Damodar, discharge observations on the site started in 1946 near Dam sites on the upper valley have mainly used float method and have employed 0·89 as the reduction co-efficient(13).

It is seen that except for the observations on the Cauvery where the co-efficient ranges from 0·77 to 0·79 the value of the reduction co-efficient is not less than 0·80 and has an upper limit of 0·95, the predominant value being above 0·85. The co-efficient is thus not constant but variable, the variation depending on the stage, depth and nature of the bed. It is said to vary directly as the depth and velocity and inversely as the rugosity.

5. Observations on Narmada at Gardeshwar

The Gujarat Engineers have been recording velocity measurements at Gardeshwar by current meter since 1961 at 0·6 depth at compartmental centres to determine the value of a suitable reduction co-efficient compartmentwise as well as for the cross section as a whole. The Hydrometeorological Year Book, 1963 for the Narmada Project received from the Government of Gujarat indicates the result of daily observations for the period 9-10-1963 to 31-12-1963. The observations at 0·6 depth are limited to maximum depth of 25 ft. as it is not possible to lower the current meter to depth below 15 ft. The depth varies from 5 ft. to 80 ft. ana the determination of the reduction co-efficient does not extend to higher gauges.

According to the observations of the Gujarat Engineers, no consistent relationship between the co-efficient and depth or Hydraulic mean depth of the section could be obtained. The table below gives the values of the reduction co-efficient at different gauge heights, together with corresponding Hydraulic mean depths.

Sl. No.	Particulars Period 9-10-1963 to 31-12-1963	No. of readings available	Co-efficient	Hyd. mean depth
1	Gauge-6-7	33	0·852	3·7
2	7-8	93	0·89	4·19
3	8-9	15	0·86	5·18
4	9-10	15	0·88	5·73
5	10-11	33	0·848	6·31
6	11-12	9	0·806	7·05
7	Observations from 9-10-1963 to 27-10-1963	57	0·85	Varies from 5·7 to 7·0
8	Observations from 29-10-1963 to 15-12-1963	93	0·864	Varies from 4·0 to 5·2
9	Observations from 16-12-1963 to 31-12-1963	48	0·827	3·7
10	Average of all the available readings	198	0·846	Varies from 3·7 to 7·0

It is also seen from the details of the daily observations that the values of the reduction co-efficient have been worked out to be as low as 0·61 and as high as 0·97.

The dominant value of reduction factor would thus appear to be 0·85 which is recommended for acceptance.

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(3) Irrigation Research Institute, Roorkee, April 1957

(4) Water Measurement Manual, U. S. Department of Bureau of Reclamation

(5) Hydraulic Measurements by Herbert Addison

(6) River Discharge by Hoyt and Grover

(7) Flow of the River Severn, 1921—36, by Dixon, Fitzigibbon and Hozan, Journal of Institute of Civil Engineers (London), June 1937.

(8) Some points in making discharge observations by E. S. Lindley, Tech. note, P. W. D. Punjab Irrigation Branch, Paper No. 6, 1923.

(9) Measurement of Flow in Water-Annual Report (Technical) of the C. B. I. (India), 1949

(10) Rivers and Canals discharge, observations for 1952—Technical Circular No. 2 of 1955, Irrigation Directorate-General, Government of Iraq.

(11) Part II Measurement of Discharge on stream gauging by Hiranandani and Chitale, C. W. & P. R. S., Poona.

(12) Manual of Instructions for surveys discharge observations and collection of silt and rainfall data—C. W. P. C. Field Investigation Administration (Flood Wing)—1956.

(13) Report of the Committee for the Augmentation of Water Resources of D. V. C., Vol. I, Dec. 1959.

CHAPTER VI

PROPOSALS OF STATE GOVERNMENTS AND GENERAL REVIEW

6·1 At the outset, the Committee requested the State Governments of Madhya Pradesh, Gujarat, Maharashtra and Rajasthan to forward their proposals on the development of the Water Resources of the Narmada Basin. The Government of Madhya Pradesh submitted an outline of a Master Plan for the development of the Valley (Document No. MP/11). Memoranda were submitted by the Governments of Gujarat (Document No. G/16) and Maharashtra (Document No. M/1) and a note on the subject was submitted by the Government of Rajasthan (Document No. R/1).

Madhya Pradesh Plan

6·2 The Plan according to the Madhya Pradesh Government aims at—

"(*i*) exploitation of the full power potential available within the State, i.e., up to about RL 200, the water level in the Narmada where it leaves Madhya Pradesh;

(*ii*) provision of irrigation facilities to all such cultivable lands in Madhya Pradesh which can be irrigated from the Narmada and its tributaries;

(*iii*) provision of navigation facilities from the mouth of the river until Hoshangabad or higher, if possible ;

(*iv*) provision of facilities for promoting fisheries;

(*v*) soil conservation of the catchment, as an integral part of the plan; and

(*vi*) development of the water resources, as indicated in (*i*) to (*v*) above, in a comprehensive and integrated manner."

6·3 Out of the total area of 38,145 square miles of Narmada basin, 33,150 square miles lie in Madhya Pradesh, 594 square miles in Maharashtra and 4,401 square miles in Gujarat State. The Narmada basin in Madhya Pradesh has been broadly divided into four distinct zones (plate V-1.)—

(1) UPPER HILLY AREAS, lying in the districts of (*i*) Shahdol, (*ii*) Mandla, (*iii*) Durg, (*iv*) Balaghat, and (*v*) Seoni.

(2) UPPER PLAINS, in the districts of (*vi*) Jabalpur, (*vii*) Narsimhapur, (*viii*) Sagar, (*ix*) Damoh, (*x*) Chhindwara, (*xi*) Hoshangabad, (*xii*) Betul, (*xiii*) Raisen, and (*xiv*) Sehore.

(3) LOWER PLAINS, in the districts of (*xv*) East Nimar (Khandwa), (*xvi*) West Nimar (Khargone) excluding Barwani Tehsil which falls in the lower hilly areas, (*xvii*) Dewas, (*xviii*) Indore, and (*xix*) Dhar.

(4) LOWER HILLY AREAS, lying in (*xx*) Barwani Tehsil of West Nimar and in (*xxi*) Jhabua district.

6·4 The Master Plan indicates for each zone the land classification, minerals, forests, climate and rainfall. Agriculture is reported to be the main occupation in Narmada basin and about 85 per cent of the population, which is estimated at six million, is reported to be rural.

6·5 In the upper hilly areas, the annual rainfall is, in general, more than 55 inches, but it goes up to 65 inches in some parts. In the upper plains from near Jabalpur to near Punasa dam site, the annual rainfall decreases from 55 inches to less than 40 inches, with a high rainfall zone around Pachmarhi where the annual rainfall exceeds 70 inches. In the lower plains the annual rainfall decreases rapidly from 40 inches at the eastern end to less than 25 inches around Barwani, and this area represents the most arid part of the Narmada basin. In the lower hilly areas, the annual rainfall again increases to a little over 30 inches.

6·6 The Plan also mentions that according to 1962-63 agricultural statistics, the total geographical area of Madhya Pradesh is 1,096 lakh acres, out of which a net area of 404·1 lakh acres or 36·9 per cent is cultivated. The area irrigated is of the order of 25·6 lakh acres, which forms 6·3 per cent of the cultivated area. Table 6·1 is illustrative:

TABLE 6·1

Details of Cultivated and irrigated area in Madhya Pradesh

Sl. No.	Year	Geographical area	Cultivated area	Area irrigated by				
				Canals	Wells	Tanks	Other sources	Total
			(Lakh Acres)					
1.	1951-52	1064·03	352·32	8·85	6·04	3·67	1·15	19·71
2.	1960-61	1095·75	397·94	10·88	8·01	3·02	0·90	22·81

The gross area of Narmada basin in Madhya Pradesh is stated to be 212·33 lakh acres, of which forests take up 70·0 lakh acres. 128·22 lakh acres are cultivable, out of which 82·2 lakh acres are sown at present annually. The area irrigated in the basin is 2·19 lakh acres, which forms 2·7 per cent of the area sown. The Master Plan envisages that, of the cultivable area of 128·22 lakh acres, nearly 77·5 lakh acres, i. e., area equivalent to 94·3 per cent of the present sown area, will be provided with irrigation facilities.

6·7 About hydrology of the Narmada river, the Master Plan states—

"Attempts have been made to determine a rainfall runoff relationship from the flow and rainfall data for the period 1948-49 to 1961-62, but because of the inadequacy of the rainfall data and the fact that the method adopted had been over-simplified, no valid relationship has so far been determined. As such, it has not been possible to prepare a useful longterm runoff series

on the basis of such a relationship. Until a valid relationship can be determined, and this is likely to take considerable time, there does not seem to be any option but to prepare a Master Plan on the basis of the fifteen years flow data available. There are indications, however, that the fifteen years, for which flow data are available, are representative of the long-term rainfall trends in the Narmada basin."

6·8 Based on this flow data, the annual river flow at 50 per cent, 75 per cent, and 90 per cent dependability at the three gauging sites on the main Narmada, namely, Jamtara, Mortakka and Gardeshwar have been worked out in Table 6·2.

TABLE 6·2

Annual river flow at Jamtara, Mortakka and Gardeshwar

Sl. No.	Site	Flow with dependability (MAF) 50%	75%	90%	Observations by
1.	Jamtara	6·87	5·89	4·80	Current meter
2.	*Mortakka	23·91	20·39	16·93	Surface velocity
3.	*Gardeshwar	29·56	21·73	18·67	" "

6·9 The Master Plan indicates the probable extent of areas to be irrigated in the first instance as 77·5 lakh acres. The water requirements for these have been worked out as 23·75 MAF. This is based on crop pattern and water requirements, taking into account the present crop pattern under unirrigated conditions and the pattern likely to develop with the introduction of irrigation. The Master Plan states—

"It is not possible, at this stage, to indicate particulars of projects or schemes which will command areas to the extent indicated above. As stated earlier, it will take considerable time even to get the maps required for the investigations. It is important, however, that every attempt should be made to provide irrigation facilities to as large an area as possible."

The major irrigation projects envisaged by Madhya Pradesh are indicated below :—

1. Bargi
2. Chinki
3. Barna
4. Tawa
5. Kolar
6. Narmadasagar (Punasa)
7. Omkareshwar (Barwaha)

* These figures are based on a reduction co-efficient of 0·80. The higher factor of 0·85 proposed by the Committee has been subsequently accepted by Madhya Pradesh, so that the figures will increase by a factor 85/80.

6·10 Crop pattern proposed zonewise, the delta adopted and the water requirements indicated by Madhya Pradesh in their Master Plan are given in Table 6·3.

TABLE 6·3

Zonewise crop pattern proposed by Madhya Pradesh, delta adopted and water requirements

Sl. No.	Name of crop	Area to be irrigated in acres	Area under crop in acres	Delta in ft. at Canal Head	Water requirements in MAF	Col. 4 as percentage of Col. 3
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	1. Upper Hilly Areas					
1.	Rice		400,000	2·50	1·00	40
2.	Other Kharif		100,000	1·67	0·17	10
3.	Wheat		150,000	1·67	0·25	15
4.	Other Rabi		100,000	1·25	0·13	10
5.	Perennials		100,000	10·42	1·04	10
		1,000,000	850,000		2·59 Say 2·70	85
	2. Upper Plains					
1.	Rice		525,000	3·33	1·75	15
2.	Cotton		350,000	2·50	0·87	10
3.	Other Kharif		525,000	1·67	0·88	15
4.	Wheat		1,225,000	1·67	2·04	35
5.	Other Rabi		350,000	1·25	0·44	10
6.	Perennials		350,000	11·11	3·89	10
		3,500,000	3,325,000		9·87 Say 9·80	95
	3. Lower Plains					
1.	Rice		300,000	5·00	1·50	10
2.	Cotton		900,000	2·50	2·25	30
3.	Other Kharif		300,000	2·08	0·62	10
4.	Wheat		750,000	2·08	1·56	25
5.	Other Rabi		450,000	1·67	0·75	15
6.	Perennials		300,000	12 50	3·75	10
		3,000,000	3,000,000		10·43 Say 10·50	100
	4. Lower Hilly Areas					
1.	Cotton		50,000	2·50	0·13	20
2.	Other Kharif		50,000	2·50	0·12	20
3.	Wheat		37,500	2·50	0·09	15
4.	Other Rabi		37,500	1·67	0·06	15
5.	Perennials		25,000	13·89	0·35	10
		250,000	200,000		0·75	80
	Grand Total ..	7,750,000	7,375,000		23·75	

6·11 According to the proposals of Madhya Pradesh, 77·5 lakh acres of area will be provided with irrigation facilities in the first instance against 128·22 lakh acres of culturable area. This is considered to be fairly modest by Madhya Pradesh and it is stated in the Master Plan that once irrigation facilities have been established to the extent of 77·5 lakh acres,

> "There is bound to be demand for extension of such facilities to other culturable areas in the basin and this fact must be borne in mind in formulating proposals for the development of the basin."

This suggests that the consumptive use may exceed even 23·75 million acre feet mentioned above.

6·12 Speaking about the limitations in framing the Master Plan, the Report states :---

> "(*a*) The Master Plan is based on inadequate hydrologic data, necessitating several assumptions in assessing the river flow available at various project sites.
>
> (*b*) The field surveys so far carried out, except in case of a few projects, are of a very preliminary nature.
>
> (*c*) Irrigation developments proposed in Madhya Pradesh, at this stage, are relatively modest. It is most likely that it will become necessary to allocate larger supplies of water for irrigation, in the years to come, with consequent reduction in power generation and in the regulated flow at Navagam.
>
> (*d*) The assumptions made for regeneration are not supported by any actual knowledge of conditions in the basin."

6·13 The Master Plan indicates, as under, the first phase of development proposed to be taken up by Madhya Pradesh Government :---

> "As the first phase of the developments in Madhya Pradesh, it is proposed to begin work, as early as possible, on the Narmadasagar (Punasa) Project, both irrigation and power, and on the Bargi Project, power only in the first instance. The Tawa and the Barna Projects, already under execution, must also be pushed through.
>
> "As soon as sufficient progress has been made on the Bargi and Tawa Projects, work would be started on the Rosra and Burhner Projects and, as soon as sufficient progress has been made on the Narmadasagar Project, work should begin on the Hiranphal Project. Irrigation development on the Bargi Project should synchronise with the availability of regulated flow from the Rosra and Burhner Projects.
>
> "The Government of Madhya Pradesh are planning to complete the work mentioned above, comprising the first phase of the Master Plan, in a period of about 10 years. Simultaneously, there will be intensive activity in the development of irrigation by medium and minor schemes in the free catchments mentioned in the Master Plan, in an endeavour to provide in this period irrigation facilities to about half of the total area to be so developed."

6·14 About power development from Narmada water resources, the Master Plan states that the short-term plans of power development in Madhya Pradesh are based on its abundant resources of inferior coal, but the long-term and ultimate objective has to be achieved only through a balanced development of hydro and thermal power resources of the State. The hydro resources are primarily said to be in the Narmada and Indravati Basins, and have to be developed to the maximum extent possible. Power generation envisaged in the Master Plan in the Narmada basin on full development of irrigation is 344 MW with 75 per cent dependable flow and 575 MW with 50 per cent dependable flow at 100 per cent load factor. The following is the list of power projects envisaged by Madhya Pradesh :—

1. Upper Narmada
2. Raghavpur
3. Rosra
4. Upper Burhner
5. Burhner
6. Basania
7. Bargi
8. Chinki
9. Boras
10. Barna
11. Hoshangabad
12. Tawa
13. Kolar
14. Handia
15. Narmadasagar
16. Omkareshwar
17. Maheshwar
18. Hiranphal
19. Jalsindhi

Plates VI-1 and VI-2 show the major irrigation and power projects according to Madhya Pradesh outline Master Plan.

6·15 Madhya Pradesh have stated that the cost of development envisaged by them may roughly be of the order of Rs. 800 crores. They have indicated that on completion of development, there would be regulated discharge of 5,030 cusecs at Navagam for 75 per cent dependable flow conditions and 10,285 cusecs at 50 per cent dependable flow conditions. This is, of course, based on the assumption of regeneration, wherein 3,460 cusecs and 4,885 cusecs, respectively, are assumed to be available as regenerated flow in 75 per cent and 50 per cent dependable flow years (with 0·80 reduction co-efficient).

6·16 The total area to be irrigated and water requirements as provided in the Master Plan would thus be as indicated in Table 6·4.

TABLE 6·4

Area to be irrigated and water requirements as proposed by Madhya Pradesh

Para.	Zone	Mean annual rainfall (Inches)	Area to be irrigated (lakh acres)	Water utilisation (MAF)
6·10	Upper Hilly Areas ..	61·3	10·00	2·70
	Upper Plains ..	49·0	35·00	9·80
	Lower Plains ..	28·0	30·00	10·50
	Lower Hilly Areas ..	30·0	2·50	0·75
	Total ..	..	77·50	23·75

Besides irrigation as indicated above, the Master Plan envisages use for power generation, annually, of 2·05 MAF of water at Bargi, 6·42 MAF at Punasa and 6·92 MAF at Jalsindhi, apart from such supplies as would be available at these sites from regeneration, on account of the irrigation uses.

Review of Madhya Pradesh Plan

Land potential for Irrigation

6·17 The irrigation potential in Narmada basin of Madhya Pradesh upstream of Punasa had been estimated at thirty lakh acres in February 1961, *vide* extracts from a joint note recorded by the then Chief Engineer, Irrigation, Madhya Pradesh, at a discussion in the Central Water & Power Commission as given below :—

> " 1. Shri Mehndiratta pointed out that according to the investigations of C. W. P. C. the gross area which can be irrigated in the valley upstream of Punasa is 44 lakhs of acres. Assuming 66 per cent of the area to be provided for under irrigation, it would amount to about 30 lakhs of acres. The main crop grown in the area will be wheat and taking duty about 2′ per acre, the water required for upstream utilisation will be 6 Maft."
>
> " 2. Mr. Sood, Chief Engineer, said that his studies had shown that the requirement of water upstream of Punasa would be about 8 Maft. In view of the fact that utilisation of this order will require very heavy investment which will run into a few decades, we may provide for 6 Maft. as a practical approach."

6·18 Later on this was confirmed by the Government of Madhya Pradesh, in Secretary, Public Works Department's D. O. letter No. 330/345/XIX/W/61, dated the 16th March, 1961, to the Chairman C. W. & P. C., given below :—

> " I am desired to refer to your D. O. letter* No. 7(9) FFI, dated (nil) February, 1961 regarding the Punasa Project and to say that the State Government agree to the reservation of upstream utilisation as proposed in your letter under reference."

6·19 Subsequently in a publication called " Irrigation & Power potentia of Madhya Pradesh Rivers" published in 1963, the irrigation likely in Narmada basin has been indicated as 46 lakh acres. The Master Plan now furnished states that the area expected to be irrigated would be 77·5 lakh acres, if water was available.

This 77·5 lakh acres, which is said to be modest and liable to further increase, has been derived from the total culturable area of 128·2 lakh acres in the basin. This total culturable area includes permanent pastures and grazing land, area covered by miscellaneous tree crops, groves, etc. Obviously it will not be correct to assume that the pasture land and groves and the entire area of culturable waste and fallow lands are available for cultivation. In any system of agriculture some amount of land has got to be left fallow for soil recuperation. Also with the increased agricultural activity consequent on introduction of irrigation, the need for bullock power and the general cattle population would go up. The necessity for pastures would be more and not less in future.

---

* Annexure VI-1

6·20 It is necessary for the country not only to conserve but also extend its tree wealth. Government have been spending a lot of money and making serious efforts to increase the area under forests. On a reference from the Committee, Madhya Pradesh Government have stated that the extent of pasture lands and area under miscellaneous trees and groves in Narmada basin in the State is of the order of 20·25 lakh acres.

Table 6·5 shows the land classification in the Narmada basin in Madhya Pradesh.

TABLE 6 5

LAND CLASSIFICATION IN NARMADA BASIN IN MADHYA PRADESH

Sl. No.	District	Area in Thousand Acres									Zone
		Gross area	Under Forest	Not available for cultivation	Total cultivable area	Permanent pasture & grazing lands	Under misc. Tree crops & groves	Net area sown	Total area cropped	Total area irrigated	
1.	Shahdol	163	29	24	110	5	1	65	78	..	Upper Hilly areas
2.	Mandla	2,801	1,311	149	1,341	118	5	798	964	3	
3.	Durg	177	86	7	84	8	..	65	72	..	
4.	Balaghat	635	356	66	213	46	9	102	110	13	
5.	Seoni	641	205	32	404	51	1	233	230	1	
6.	Jabalpur	1,460	311	107	1,042	152	26	644	729	15	Upper Plains
7.	Narsimhpur	1,230	338	60	832	121	17	609	630	10	
8.	Sagar	172	45	7	120	33	..	57	59	..	
9.	Damoh	110	46	6	58	12	1	34	37	2	
10.	Chhindwara	911	324	52	535	70	2	346	388	15	
11.	Hoshangabad	2,461	707	152	1,602	215	12	973	986	25	
12.	Betul	959	441	43	475	91	1	258	270	11	
13.	Raisen	1,199	468	48	685	99	..	486	489	6	
14.	Sehore	902	327	43	532	142	11	318	323	7	
15.	East Nimar (Khandwa).	1,781	655	105	1,021	229	13	739	765	20	Lower Plains
16.	West Nimar *(Khargone).	2,368	844	175	1,549	215	1	1,193	1,289	41	
17.	Dewas	926	23	152	751	63	7	339	346	3	
18.	Indore	282	89	16	177	58	..	106	115	8	
19.	Dhar	1,210	131	193	886	154	..	626	689	35	Lower Hilly Areas
20.	West Nimar (Barwani Tehsil).	400	237	36	127	13	..	109	116	4	
21.	Jhabua	245	35	30	180	23	..	112	121	..	
	Total	21,233	7,008	1,403	12,822	1,918	107	8,224	8,885	219	

2,025 or 20·25 lakh acres

*Excluding Barwani Tehsil

6·21 If the figure of 20·25 lakh acres under permanent pastures, grazing lands and miscellaneous tree crops and groves, etc., is deducted, the net cultivable land including culturable waste would be of the order of about 108 lakh acres. A considerable part of this would not be available for irrigation as it would be submerged by the big reservoirs on the Narmada and by the very large number of medium and minor works which the State Government propose to construct on the tributaries of the main river for local irrigation. It has also to be borne in mind that the minor and medium works will have to be constructed at an appreciable distance from the ridges of the catchments, in order to leave enough area for providing the inflow for storage works. Such areas, being upstream of the storages, would not naturally get irrigation. Allowing for these, the net cultivable area in Madhya Pradesh in the Narmada basin will be as worked out below:

	Lakh acres
Total culturable area as indicated in Madhya Pradesh Master Plan (inclusive of pastures, area under miscellaneous tree crops, culturable waste, etc.)	128·22
Less area under pastures and Miscellaneous tree crops, etc., not considered as available for irrigation.	— 20·25
Total culturable area	107·97
Less—	
(*i*) Culturable area likely to be submerged under Major projects	
At 50 per cent of total submergence (vide Statement IX of Madhya Pradesh Master Plan), i. e., 50 per cent of 6,82,000 acres	3·41
(*ii*) Culturable area likely to be submerged under Medium and Minor irrigation works.	
At 20 per cent of the total area to be irrigated (say 40 lakh acres)	8·00
(*iii*) Fringes of the basin watershed to provide catchment for minor/medium irrigation works 40 lakh acres at 2·4 ft. overall delta requiring 9·6 MAF of water.	
The average run-off at Hiranphal with a catchment area of 31,409 sq. miles is 34·22 MAF	
At the above rate the catchment required to provide runoff of 9·6 MAF would be of the order of 8,800 sq. miles.	
Taking 25 per cent of this as culturable, area not available for irrigation	14·00
Total deduction ..	25·41
Net available cultivable area ..	82·56
	Say 83 lakh acres

Allowing for the fact that land close to drainages would be uneven and cut up, it may be assumed that the total irrigation which would be theoretically possible in the basin in Madhya Pradesh on full development would be less than 83 lakh acres.

6·22 In this connection the following extract from the note on "Agro-economic Aspect of Irrigation Potential in the Narmada Valley in Madhya Predesh" prepared by the Madhya Pradesh Electricity Board, a copy of which was given to the Committee during its visit to Madhya Pradesh areas on the 7th April, 1965, is relevant:—

> "It will be possible to bring about 5 million acres within the actual command of the various projects envisaged, both by gravity flow and lift irrigation. Net cropped area can be safely taken as 4 million acres."

Dealing with the water requirement, the above note states that "the total water requirements of the area will be 13·37 MAF. This is exclusive of canal losses. The total requirements may, therefore, be well above 15 MAF."

6·23 The Planning Commission in their Report on the Third Five-Year Plan have stated :

> "By realising the entire potential for irrigation of 175 million acres (gross) over the next 20—25 years (by which time the cultivated area may increase to about 350 million acres) the proportion of irrigated lands may perhaps rise to 50 per cent."

Assuming that the whole of the 83 lakh acres mentioned in para. 6·21 above is cultivated, the proportion of irrigated land should be of the order of 50 per cent or 41·5 lakh acres on the basis of the all-India irrigation pattern.

On the assumption, however, that some pasture lands also might be brought under irrigation and minor irrigation schemes might expand to some portions of the fringe areas and also to areas otherwise inaccessible to irrigation, the Committee would be glad to raise this figure of 41·5 lakh acres to as high a figure as the upper riparian State could possibly bring under irrigation even in the distant future.

Allowing the fullest freedom for irrigation to Madhya Pradesh, the Committee feel that this figure will in no case exceed 65 lakh acres (which will be 78·3 per cent of the culturable area) with possible annual utilisation of 15·6 MAF of water (Para. 7·13 of Chapter VII).

Runoff availability

6·24 Madhya Pradesh have stressed that the runoff figures should be based only on the 15 years for which actual flow data is available. It is an established scientific method to project a long term series from observed flow data, especially where rainfall data records are available for a number of years and flow

data for only a few years. The statistical analysis of such data has been perfected so well that almost all the irrigation and power schemes that are being formulated at present, not only in India but also abroad, depend to a large extent on such projected runoff series.

The Committee are, therefore , unable to accept the suggestion made by Madhya Pradesh.

Crop pattern and water requirements

6·25 The proposed crop pattern and water requirements in the Master Plan, as indicated in para. 6·10 above, have been carefully gone into and dealt with in Chapter VII, paras. 7·5 to 7·11. While the proposal for foodgrains and fibres are generally based on present pattern of agriculture, the percentage proposed for perennials appears to be much on the high side. The losses of $66\frac{2}{3}$ per cent assumed between the field and the canal head, are also on the high side.

Phasing of development

6·26 The first phase of development envisaged by Madhya Pradesh, *viz.* construction of Punasa, Bargi, Tawa, Hiranphal, Rosra and Burhner, and provision of irrigation to about half the total area to be so developed in a period of 10 years, appears to be unrealistic. The cost of these developments will run into Rs. 380 crores. While it is expected that work on these developments will proceed at par with the best achievement anywhere in India, the programme envisaged in the first ten years is likely to be spread over 20 years or so, taking into account the limitations of technical manpower, money and materials.

Consumptive use for irrigation

6·27 The Madhya Pradesh Master Plan, on full development, aims at utilising 23·75 MAF to irrigate about 77·5 lakh acres of land and generate power of the order of 344 MW at 100% L. F. only in the entire Narmada basin in Madhya Pradesh in a year with 75 per cent dependable flow.

The Committee feel that without placing any restriction on irrigation development in Madhya Pradesh, the consumptive use of water on a realistic plan will be appreciably lower and power potential much greater than that envisaged by Madhya Pradesh (vide Chapter VII, para. 7·13 and Chapter XII, Para. 12·7).

Summary

6·28 In brief, the Madhya Pradesh Master Plan envisages utilisation of 23·75 MAF of Narmada waters to provide irrigation facilities to an area of 77·5 lakh acres. With this utilisation for irrigation, the power generation would be only 344 MW at 100% L. F. in the whole basin in Madhya Pradesh in a year of 75 per cent dependability. The availability of waters is based on 15 years observed data at the three discharge sites on the Narmada and one discharge site on its tributary Tawa.

In the view of the Committee, an area of 65 lakh acres in the Narmada basin in Madhya Pradesh would be the very outside figure for providing irrigation facilities. The water requirements for this area have been worked out as 15.60 MAF in para. 7·13 of Chapter VII. The power generation in that case has been indicated in para. 12.7 of Chapter XII. This would provide Madhya Pradesh with sufficiently large area under irrigation and considerably larger quantum of power.

Gujarat Plan

6.29 In their memorandum submitted to the Committee, the Gujarat Government have indicated that the total geographical area of Gujarat State is 442 lakh acres, out of which 232 lakh acres or 52·5 per cent are cultivated every year. Over 25 per cent of the total area is said to be barren and uncultivable. The area under forests is 8 per cent.

Of the cultivable area, about 53·5 per cent is under food crops, the main crops being jowar (16 per cent) and bajra (14.5 per cent). The remaining area is under non-food commercial crops, mainly cotton (20 per cent) grown mostly in Gujarat region and groundnuts (25 per cent) grown mostly in Saurashtra region.

6·30 The rainfall in the Southern plains of Gujarat varies from 30″ to 50″, in Central plains from 20″ to 45″ and in the Northern plains from 15″ to 40″. In Saurashtra and Kutch areas, the rainfall ranges between 10″ and 25″ inches. Plate VI-3 shows the Gujarat area indicating the various districts and the annual isohyetals.

It is seen from the isohyetals map that out of the total land area of 442 lakh acres, 81 lakh acres or 18 per cent have rainfall below 15,″ 247 lakh acres between 15″ and 30″ and 114 lakh acres between 30″ and 50″. Thus, in about 18 per cent of the total area, conditions of semi-aridity prevail and in another 55 per cent, rainfall can be considered meagre to average. The desert sandy areas in the Rann of Kutch (aggregating about 60 lakh acres) have annual rainfall of less than 10″. Apart from the failure of the monsoon which is of frequent occurrence, the distribution of rainfall even in good years is not satisfactory over the entire monsoon period. Dependence of agriculture on low and ill-distributed rainfall has frequently led to scarcity conditions in many parts of the State.

6·31 The memorandum states that arid areas with low rainfall have high sodium chloride content at surface which is responsible for low yields per acre. With irrigation facilities the salt content can be leached down and the fertility of the soil improved. Poor yields are also attributed to the erratic nature of rainfall in general. The common practice is to raise only one crop per year and the cropping pattern is predominantly kharif.

6·32 At present, the percentage of irrigated area to that under cultivation is only about 7·5 as against over 17 per cent for the whole country. Again, of the total area irrigated, as much as 83 per cent is irrigated by private wells, which is a slow and costly method. The percentage of cultivated land having irrigation facilities would rise to only 9·39 by the end of the Third Plan. Table. 6·6 is illustrative:—

TABLE 6·6

Details of cultivated and irrigated areas in Gujarat

Sl. No.	Year	Geo-graphical area	Culti-vated area	Area irrigated by				
				Canals	Wells	Tanks	Other sources	Total
				(Lakh acres)				
1	1956-57	444·0	229·3	1·31	11·28	0·69	0·25	13·53
2	1960-61 ..	442·7	232·2	1·63	14·03	0·32	0·90	16·88

6·33 According to the memorandum, the Gujarat Government have already planned for utilising, to the maximum extent possible, the available waters of the Tapi, Mahi and Sabarmati rivers and the Narmada river is the only source left for supplying irrigation waters to the vast arid regions in Gujarat. The Narmada Project can serve a gross area of 87·64 lakh acres accounting for about 20 per cent of the total geographical area of the State. Over 72 per cent of the gross area is reported to be affected by varying degree of scarcity conditions. The great necessity for providing irrigation facilities to these lands is, therfore, emphasised.

6·34. The Navagam project (January 1965), as proposed by the Government of Gujarat in their memorandum, envisages the construction of a high dam at Navagam to FRL+490, a high level canal (taking off at RL+300) nearly 300 miles long and irrigation facilities to 34·74 lakh acres. Table 6·7 gives the details of the command area under Navagam RL+300 canal:—

TABLE 6·7

Details of Command Area under Navagam+300 canal

(Lakh acres)

Sl. No.	Zone	Average annual rainfall in inches	District	Gross Area	Cultivated Area	Area proposed to be irrigated
1	2	3	4	5	6	7
1	Area under original +158 level canal and zones I, II, and III.	31·7	Broach, Baroda and Panchmahal.	19·23	14·12	11·05
2	IV ..	32·0	Kaira ..	1·60	1·29	0·84
3	V, VI, VII, VIII, IX and XI.	22·0	Ahmedabad, Bhanv-nagar, Surendra-nagar, Mehsana and Kutch.	48·13	30·53	16·87
4	X ..	20·0	Banaskantha ..	9·68	4·57	2·98
5	XII (Little Rann of Kutch).	10·0	Kutch ..	9·00	6·00	3·00
	Average ..	22·9	Total ..	87·64	56·51	34·74

The entire development is proposed in three stages: Stage I—up to Mahi to irrigate about 14 lakh acres ; Stage II—to extend this irrigation up to the Rann of Kutch and irrigate about 25 lakh acres ; Stage III—envisages extension of irrigation to the areas in Saurashtra and Kutch. The water requirements for the three stages have been estimated at 4·7, 9·5 and 13·2 MAF, respectively.

These figures do not include irrigation of 6·57 lakh acres of Mahi command which can be served by the Narmada Canal and the 4·5 lakh acres in the Great Rann of Kutch.

Plate VI-3 referred to in para. 6·30 also shows the Navagam dam site, the proposed alignment of the high level canal and the commanded area.

6·35. The canal will take off at RL+300. The reason for not choosing a higher level is stated to be as under:—

> "The additional areas which can be commanded by raising canal offtake above RL 300 are comparatively limited on account of the steep rise in the general ground levels above this contour. Besides, the proportion of the C.C.A. to the gross area in the belts between RL 300 to RL 350 and RL 350 to RL 400 is also less, since a sizeable portion of the area lies in hilly region of poor soil and very uneven topography. The cost of the canal in this area will also be higher since it would be running through highly undulating country for the first about 100 miles."

The command of the project with FSL+300 includes high areas of Saurashtra and Kutch which are proposed to be served by lifts of 150 to 250ft. The extent of such irrigation is 6·8 lakh acres and the water requirement for it is about 2 MAF.

6·36 As regards the lift irrigation mentioned in para. 6·35 above, the report says—

> "Preliminary studies have established that power required for meeting peak demand of irrigation under the lift areas (with area under annual irrigation of 6·8 lakh acres) can be met to a large extent from the hydropower generation at the fall (70') on the main Saurashtra Branch close by. Since power generation would be almost synchronous with the demand, the same can most economically be used for lift irrigation. The pumping cost is, therefore, expected to be low."

6·37 Besides provision of irrigation to 3 lakh acres in the Little Rann of Kutch, Gujarat Government have submitted a separate note on the possibilities of reclamation and irrigation in the Great Rann of Kutch. It is said that the Banni area of the Great Rann could be reclaimed. A canal taking off from the high level canal is expected to command a cultivable area of 9 lakh acres and, with 50 per cent intensity of irrigation, an area of 4.5 lakh acres is said to be available for irrigation. The irrigation proposed, including double cropping, it is said, could be 7·65 lakh acres. The annual water requirements have been estimated at 2·45 MAF.

6·38 Although the Mahi canal area (Stage I) of 6·57 lakh acres can be easily served from Narmada waters, the project, as proposed by the Government of Gujarat, does not provide for such take over, except for temporary supplemental supplies of 0·72 MAF in the initial stages. The area is ultimately intended to be irrigated by Mahi water stored in the proposed Kadana dam.

In a subsequent note dealing with water resources of all the rivers crossed by Navagam Canal and proposals for their utilisation submitted by the Gujarat Government to the Committee in May, 1965, they have stated that in case the areas now lying under the Mahi command are irrigated by the Narmada waters, the storage at Banswara and Kadana on the Mahi can be utilised by a high level canal from the Kadana dam to irrigate areas in the Gujarat State above the Navagam Canal. This would necessitate an additional requirement of 1·9 MAF from Navagam reservoir to irrigate an area of 6·57 lakh acres.

6·39 The total area to be irrigated and water requirement as provided by Gujarat, also areas and water requirements of Mahi and Great Rann of Kutch would thus be 17·55 MAF as detailed in Table 6·8:—

TABLE 6·8

Areas to be Irrigated and Water Requirements as Proposed by Gujarat

Para.	Zone	Mean annual rainfall (Inches)	Area to be irrigated (Lakh acres)	Water utilisation (MAF)	Remarks
6·34	Area other than Ranns of Kutch.	24	31·74	11·56	
6·34	Little Rann of Kutch ..	10	3·00	1·64	
6·37	Great Rann of Kutch ..	10	4·50	2·45	
6·38	Mahi command transferred to Navagam canal.	32	6·57	1·90	The Mahi water 1·9 MAF will be transferred to Rajasthan.
	Total ..		45·81	17·55	

6·40 The duties for the various crops in the Narmada project are the same as those in the sanctioned Broach irrigation project but the crop pattern is said to be based on detailed soil surveys and investigations carried out by the Agronomists and other experts. Table 6·9 indicates the various crops proposed under the Narmada project, the delta adopted and the water requirements. These do not include the Mahi area and the area of the Great Rann of Kutch.

TABLE 6·9

Crop Pattern and Water Requirements (As proposed under Gujarat Plan)

Name of crop	Area under crop in acres	Net delta in ft. at the canal head	Water requirement in acre ft.	Col. 2 as percentage of total area
1	2	3	4	5
A. Perennials				
(*i*) Sugarcane (Heavy) ..	1,06,058	15·521	16,46,126	3·05
(*ii*) Light perennials ..	1,27,258	9·991	12,71,434	3·66
B. Kharif				
(*i*) Kharif oilseeds ..	3,58,770	0·841	3,01,725	10·33
(*ii*) Paddy (Fine) ..	2,82,461	5·234	14,78,400	8·13
(*iii*) Paddy (coarse) ..	2,82,461	3·831	10,82,108	8·13
(*iv*) Kharif cereals and fodder	6,07,428	0·841	5,10,846	17·49
C. Rabi				
(*i*) Wheat ..	6,90,826	1·85	12,78,028	19·89
(*ii*) Wheat (follow on) ..	2,64,061	0·788	2,08,080	7·60
(*iii*) Ravi oilseeds and pulses	3,03,830	1·85	5,62,086	8·75
(*iv*) Rabi vegetables ..	89,100	1·85	1,64,835	2·57
D. Hot Weather				
(*i*) Hot weather vegetables	97,423	3·04	2,96,166	2·80
(*ii*) H. W. fodder & green manure.	2,53,767	3·04	7,71,452	7·31
E. Eight Monthly				
(*i*) Cotton ..	9,57,806	2·451	23,47,582	27·57
(*ii*) Cotton (Pre-seasonal) ..	9,57,806	1·15	11,01,477	..
(*iii*) Cotton (Rabi) ..	14,391	1·56	22,450	9·42
(*iv*) Tobacco ..	50,190	3·226	1,61,913	1·44
Total ..	..	..	1,32,04,708	129·14

.. i. e. 13·20 MAF

6·41 Gujarat Government have carried out extensive soil surveys and sub-soil water investigations in the area of the Rann of Kutch and according to their soil experts, there is reason to believe that some of the lands can be reclaimed and made fit for cultivation if adequate quantity of waters were available for the purpose. The Gujarat Government have also done some pot experiments in this connection, which have given encouraging results. They propose further to work on a Pilot scheme of about, 5,000 acres in the field to confirm the conclusions drawn from pot experiments.

At the request of the Committee, the Gujarat Government submitted in March, 1965 a report on the possibilities of reclamation in the Great Rann of Kutch. They propose to provide irrigation facilities to an area of 4·5 lakh acres.

6·42 According to the Gujarat memorandum it would be possible to generate power of the order of 679 MW at 60 per cent load factor at the river bed and canal bed power houses with the Navagam dam at FRL+490. This assumes utilisation of 6·8 MAF of water annually to irrigate 32 lakh acres of area in Madhya Pradesh and irrigation withdrawal of 13·08 MAF for areas under the Navagam Canal.

Review of Gujarat Plan

Land Potential for Irrigation

6·43 The Gujarat State have proposed irrigation for an area of 34·74 lakh acres against the total cultivable area of 66·40 lakh acres. This works out to an irrigation intensity of 52 per cent and is comparable with the all-India figure of 50 per cent as indicated in para. 6·23 above.

6·44 The Gujarat Government have proposed to irrigate areas in Little Rann and Great Rann of Kutch. It is hoped that experiments in this direction will be carried out soon, and it would be possible to express a definite opinion on the feasibility of reclamation of these areas. From information available todate such reclamation would appear to be feasible.

The Committee are strongly of the view that the low-lying areas of the Great Rann of Kutch, which presently get flooded partly from inland streams and partly from sea water, should be reclaimed by isolating them from the sea with the construction of a bund approximately 25 to 30 miles long at the mouth of the Rann, across the Khori Creek. There can be provision for letting out the fresh waters of the floods at low tide and otherwise by pumping. In the dry weather these areas can be provided canal waters for leaching out salts in the early years and for irrigation thereafter. These are the areas bordering Pakistan which are meant for the settlement of new cultivators and otherwise made accessible and fit for permanent habitation. The development of this area should proceed simultaneously with those of the Banni area.

Crop Pattern and water Requirements

6·45 Table 6·4 shows that it is intended to use about 2·5 MAF of water for irrigation of about 6 lakh acres of paddy, and 3 MAF for 2.3 lakh acres of perennials while another million acre feet is needed for vegetables, fodder and green manure.

There appears to be considerable scope for revision of crop pattern and reduction in demand for water. In the intital period of several years while irrigation in Madhya Pradesh is being developed, there would be plenty of water which can be used for imporoving salt affected lands and reclaiming areas in Rann of Kutch but in the final pattern the water allotment would have to be limited to a reasonable figure consistent with the requirements of Madhya Pradesh.

Extension of Irrigation to international border areas of Rajasthan

6·46 The Gujarat memorandum does not mention anything about conveyance of water to Rajasthan areas lying to the north of the State border. This part of Rajasthan which lies close to the international boundary with Pakistan is at present an uninhabited desert as it receives little rainfall and even drinking water is difficult to get. Provision of irrigation facilities here would ensure attracting a stable prosperous population of hardy agriculturists along the border.

6·47 According to the levels of the Navagam canal (RL+300) an area of 1·5 to 2 lakh acres (gross) in Rajasthan can receive flow supply, actual irrigation being 1·0 lakh acres.

Larger areas of higher ground can, however, be irrigated by lift. As lift irrigation would be expensive and power would be difficult to obtain, the possibility of providing flow irrigation to this additional area has been considered. This is possible by transferring Mahi command in Gujarat to the Navagam canal and transferring equivalent water of the Mahi released thereby to Rajasthan through a canal from Kadana dam which will be at a much higher level. This is discussed in greater detail in Chapter VIII.

Summary

6·48 Against the proposals of Gujarat, as modified to include Mahi command, the Great Rann of Kutch and border areas in Rajasthan, given in para 6·39, the Committee are of the view that irrigation facilities under the Navagam canal (FSL+300) should be provided to as large an area as possible inclusive of taking over the Mahi command, the Great Rann of Kutch and also to international border areas in Rajasthan. The area to be irrigated from the Narmada in Gujarat and Rajasthan thus comes to 46·8 lakh acres with possible annual utilisation of 11·24 MAF (paras. 7·19 and 7·20 of Chapter VII), less 0·34 MAF inflows into the Navagam canal which will be available from minor streams enroute (Para. 8·3 of Chapter VIII) or a net annual utilisation of 10·90 MAF.

The possible power generation at Navagam has been dealt with in para. 12·7 of Chapter XII.

Maharashtra

6·49 The Maharashtra Government in their Memorandum have stated that the area of their State in the Narmada basin consists mostly of forests or hills with scattered patches of cultivation, and the scope of irrigation is, therefore, limited. They desire that 0·1 million acre feet of water should be reserved for them for possible irrigation of about 10,000 acres by pumping.

6·50 In the power studies made by Maharashtra in connection with their memorandum, they have estimated that with a high level dam at Jalisindhi, with no Hiranphal, and Navagam dam at FRL+210 , power generation would be maximum, more dependable and cheaper. They have also expressed the opinion that a high dam at Navagam was likely to suffer from earth tremors, that the geological conditions at site were not so good as those at Jalsindhi and there was a possibility of valuable flouride and other minerals being permanently submerged and lost.

6·51 Maharashtra have subsequently expressed agreement with the proposal of Madhya Pradesh to have a high dam with FRL+465 and MWL+470 at Hiranphal and another dam with FRL of about+355 and tail water level of about+210 at Jalsindhi. In their view the Navagam dam should have FRL of about+210 and the canal should take off at about+190/185. According to them this lower canal would command the greater part of the area proposed to be irrigated by the RL +300 Canal, while the rest could be served partly by transferring the Mahi area lying to the left of the low level canal to the Narmada, and releasing corresponding amount of Mahi water for irrigating lands between+300 canal and the+190/185 canal and partly by lifting water from the lower canal to irrigate the higher areas.

In a subsequent note handed over to the Committee at Bombay (10th June, 1965), Maharashtra have said that for a low level canal it would not be necessary to incur the expenditure and loss of head involved in taking off the canal from the present dam site and it would be better to shift the site to where it was originally proposed. Their studies indicate that the+185/190 canal, with suitable adjustment of slope and avoiding loss of head at river crossings would be able to reach the Rann of Kutch and would be able to make use of all the water that was likely to reach Navagam after the completion of irrigation developments in the Madhya Pradesh Master Plan.

6·52 They have given , in detail, their requirements of power during the next three Plan periods, their expectations of power from other sources, and have asked for a minimum allotment of 1,000 MW at 60 per cent load factor from the Narmada Hydro-electric Stations.

Review of Maharashtra Plan

6·53 The water requirements of Maharashtra for irrigation are very small and can be fully met without affecting utilisation in Madhya Pradesh and Gujarat. The question of offtake levels of Navagam canal has been fully dealt with in paras. 12·11 and 12·12 Chapter XII.

As regards power, the proposals of the Committee about generation and allocation are given in detail in Chapter XII. (Para. 12·7) and XIII (Para. 13·6). The comparative merits of the Jalsindhi dam have also been discussed in Chapter XII.

Rajasthan

6·54 The Rajasthan Government have in their note of 17th December, 1964 stated that the lands in their State, lying to the North of Gujarat border, have no source of irrigation and can be irrigated only if supplies are given to them from the Narmada or from the Mahi. According to levels, the Navagam +300 canal which would deliver water at about RL+100 at the Gujarat-Rajasthan border, can command only about 1·8 lakh acres of gross area and actual irrigation of one lakh acres in Rajasthan, but if the canal could be taken out at a higher level from Navagam, larger areas could be served. According to them, the Mahi canal from Kadana with full supply level at head of +380 would deliver water to their borders at about RL+300 and command a gross area of about 11·5 lakh acres, including the 1·8 lakh acres coming under Navagam+300 canal.

6·55 Dealing with their power requirements, the Government of Rajasthan have stated that no cheap power is available in the State and this has affected the industrial development and exploitation of its vast and precious mineral deposits. Rajasthan, having neither oil nor coal nor perennial rivers, has to depend upon costly fuels transported from long distances which make its power generating cost very high.

They have also indicated that in a meeting held between the representatives of Madhya Pradesh and Gujarat Governments at Jabalpur in June, 1962, both the State representatives were pleased to concede that 50 MW of power might be reserved for Rajasthan from the Narmada Project (Annexure VI-2). Even with 50 MW from Narmada, Rajasthan would be facing continuous shortage of power. They have reviewed their power position and in view of the shortage, they have asked for at least 100 MW of power to enable the State to exploit its vast mineral resources which will otherwise lie dormant because of lack of power.

Review of Rajasthan Proposals

6·56 The Committee are of the view that the 1·8 lakh acres gross (1 lakh irrigation) should receive water from the Narmada canal and the balance of area (11·5—1·8=)9·7 lakh acres which cannot be irrigated by flow should be served from the Mahi-Sabarmati complex discussed in Chapter VIII.

The Committee do not recommend raising the FSL of Navagam Canal beyond RL+300.

The recommendations of the Committee about the demand of Rajasthan for power are contained in Chapter XIII.

ANNEXURE VI-1

Copy of D. O. letter No. 7(9)/60-FFI, dated the 20th February 1961 from Shri M. Hayath, Chairman, C. W. & P. C. addressed to Shri N. P. Dikshit, Secretary to the Government of Madhya Pradesh, P. W. D., Bhopal.

Please refer of your D. O. letter No. 167/106/XIX/M/61, dated the 24th January 1961 to Ahuja

We have since been able to hold discussions with Shri M. L. Sood about the technical aspects of the water utilisation for Punasa Project. A copy of the agreed technical note in this connection is enclosed. A perusal of the same would show that at least 4 Maft. would be available for utilisation in 90 per cent years and about 8 to 9 Maft. would be available for 75 per cent years, which is the basis of all irrigation projects. This amount would be more than adequate to meet all physically possible requirements upstream of the Punasa Dam.

It is requested that the approval of Madhya Pradesh Government to the reservation of upstream utilisation proposed in the agreed technical note may kindly be communicated at an early date.

It is further requested that your concurrence in the matter may kindly be intimated within a fortnight so that this project which has been pending for a long time can be finalised early.

In case no reply is received from you within the period mentioned above, your concurrence would be presumed and necessary steps would be taken to finalise the report.

The Ministry of Irrigation and Power is being apprised of the up to date position.

ANNEXURE VI-2

Minutes of the meeting held in the office of the Chairman, Madhya Pradesh Electricity Board, Jabalpur, in connection with the development of the Narmada Valley.

12-6-1962 & 13-6-1962

The following representatives of Gujarat and Madhya Pradesh Governments met at Jabalpur from 4-00 to 7-00 P.M. on the 12th June 1962 and from 11-00 A.M. to 1-00 P.M. on the 13th June 1962.

Gujarat	Madhya Pradesh
1. Shri H. M. Patel, Chairman, Gujarat Electricity Board.	1. Shri S. N. Mehta,, I.C.S., Chairman, Madhya Pradesh Electricity Board.
2. Shri G. L. Sheth, Secretary to Government of Gujarat, P.W.D.	2. Shri M. L. Sood, C.E., Government of Madhya Pradesh.
3. Shri G. G. Dhanak, C.E. & Jt. Secretary to Government of Gujarat.	3. Shri B. L. Penday, Fin. Member, M. P. Electricity Board.
4. Shri C. C. Patel, S.E., Narmada Irrigation Circle	4. Shri M. Y. Koli, C.E., M. P. Electricity Board.
5. Shri R. P. Desai, Technical Member, Gujarat Electricity Board.	5. Shri N. Tata Rao, Secretary, M. P. Electricity Board.
	6. Shri L. J. Sane, Dy. C. E. (Gen.), M. P. Electricity Board.
	7. Shri R. S. Kurpad, S.E. (C), M.P. Electricity Board.
	8. Shri R. C. Shrivastava, Deputy Secretary to Government of M. P.

1. Each item on the agenda were discussed in detail and the following conclusions were reached.

2. As, without the execution of the Punasa Project, adequate power generation is not possible at Navagam, these two projects must be simultaneously executed.

3. The execution of the Punasa Project, however, would result in the submergence of considerable area of extremely fertile agricultural land and would lead further to the displacement of a large number of people. It was recognised, therefore, that alongwith Punasa and Navagam, the Bargi Irrigation-*cum*-Power Project should also be undertaken in order to facilitate the rehabilitation of the displaced persons as well as to irrigate about 7 lakhs of acres of good agricultural land.

4. In addition, the question of certain smaller Irrigation-*cum*-Power Projects upstream of Punasa remains to be considered. There should be no difficulty in these being taken up, as and when required.

5. As the expeditious and co-ordinated execution and financing of these projects, because they lie in two States, is of the utmost importance, it was agreed that an autonomous body should be set up. This, however, would raise a number of problems. A general discussion on this subject took place and various possibilities were explored. It was felt that no object would be served in going into more details about it, since this subject has already been entrusted by the Government of India to Shri H. M. Patel, who it was understood, would later hold discussions with the State Governments concerned.

6. According to the load forecast of the C.W.&P.C. which is on the conservative side, the entire output of the Narmada Valley will be required to meet the demands of Madhya Pradesh and Gujarat. But considering that Rajasthan has no other source of supply, 50 MW of power may be reserved

for them. The Maharashtra position is somewhat different, as thermal stations are being established at Akola and Bhusaval. If, however, they can establish the priority of their requirements, it may be considered.

7. The question of financial participation by Maharashtra and Rajasthan in the development of Narmada Valley, particularly from the point of view of power generation, does not really arise, as the projects are multipurpose, *i.e.*, both for irrigation and power. The object of these two States in offering financial participation is to assure themselves of allotment of certain power which can be met by an undertaking by Madhya Pradesh and Gujarat to all such power as may be agreed to at the time, according to power availability and other considerations.

8. In view of the urgency of developing the Narmada Valley Power, the question of inter-connecting the M. P.-Rajasthan Grid with the Gujarat Grid on a priority basis needs to be examined by the two State Electricity Boards.

H. M. PATEL
Chairman
Gujarat Electricity Board

S. N. MEHTA
Chairman
Madhya Pradesh Electricity Board

CHAPTER VII

CROP PATTERN AND WATER REQUIREMENTS

7·1 The Delta for an irrigated crop is the total depth of water required to bring the crop to maturity. Delta depends on the nature of crop, kind of soil and climatic conditions. Where monsoon rainfall or winter showers give appreciable assistance to growth of plants, the amount of water required from artificial irrigation is correspondingly reduced.

The use of fertilisers will produce little result if water supply is inadequate. If supply is adequate, the use of fertilisers will increase yields and these yields will generally rise with the increase in the quantity of fertiliser used till the optimum limit is reached. But increase in use of fertilisers will not need any appreciable increase in irrigation water.

7·2 Delta is expressed in inches (*a*) at the field or (*b*) at the distributary head including loss in distribution system or (*c*) at canal head which includes entire loss from canal head to field. The loss in transit depends on soil, temperature, humidity, subsoil water level, whether a channel is lined or unlined and the general layout of the canal system.

7·3 When canal water comes into any area the cultivators start using better seeds suitable for irrigated conditions to get higher out-turn. Some crops normally grown during the monsoon, such as cotton, jowar, maize, etc., are sown a few weeks earlier with canal water to get full benefit of growth during the rainy season. Very early sowing of jowar for use as fodder only is done to some extent and limited areas of crops such as lucerne, berseem, etc., are also cultivated to provide fodder for cattle in the hot season. Cash crops such as groundnut, sugarcane, fruits and vegetables are cultivated in places where soil conditions are suitable and marketing facilities are available. There would, on the whole, however, be no large change in the existing crop pattern on the introduction of irrigation.

7·4 The probable crop pattern and water requirements of the Narmada basin after development of irrigation are indicated in the following paragraphs.

Madhya Pradesh

Major Projects

7·5 In statement XII-B on page 21, Volume II of the Madhya Pradesh Master Plan, a list of major projects which Madhya Pradesh propose to execute is

given and is reproduced as Table 7·1

TABLE 7·1

Area proposed to be Irrigated by Madhya Pradesh under Major Projects

Serial No.	Name of Project	Area proposed to be irrigated (Acres)	Zone
1	Bargi ..	6,60,000	Upper Plains
2	Chinki ..	1,50,000	
3	Barna ..	1,21,000	
4	Tawa ..	7,50,000	
5	Kolar ..	50,000	
		17,31,000 acres	
6	Narmadasagar (Punasa) ..	6,00,000	Lower Plains
7	Omkareshwar (Barwaha) ..	3,43,000	
		9,43,000 acres	
	Total ..	26,74,000 acres	

According to this list, none of the projects lie in the upper hilly areas or the lower hilly areas. It is presumed that in these latter areas irrigation will be done by medium and minor works situated on the tributaries of the Narmada.

Table 7·2 gives the existing crop pattern, the crop pattern proposed by Madhya Pradesh under the Master Plan (1965) after irrigation is introduced and the pattern as recommended by the Committee, based on the observations made in para. 7·3 above.

TABLE 7·2

Existing and proposed crop pattern in Madhya Pradesh

Serial No.	Zone	Crop	Crop pattern		
			Existing Av. of (1956—1961) percentage of sown area	Proposed by M. P. percentage of culturable command	Recommended by the Committee
1	Upper plains*	Rice ..	7·1	15	15
		Other Kharif ..	24·0	15	20
		Wheat ..	36·4	35	40
		Other Rabi ..	33·9	10	20
		Cotton ..	1·6	10	..
		Perennials ..	0·9	10	5
	Lower plains*	Rice ..	3·1	10	5
		Other Kharif ..	41·9	10	35
		Wheat ..	17·4	25	25
		Other Rabi ..	19·6	15	5
		Cotton ..	21·2	30	25
		Perennials ..	0·7	10	5

*Vide Chapter VI Para. 6·3.

7·6 Table 7·1 above would show that Madhya Pradesh propose to irrigate 26·74 lakh acres from major works out of the 77·5 lakhs of total area in the basin proposed for irrigation facilities. It has been stated by the Committee in Para. 6·23 of Chapter VI that actual area which is likely to be available for the purpose will not be more than 65 lakh acres.

As the reasons for the lower figure for irrigation given in that Chapter would apply mostly to cases of medium and minor works, the total figure for major irrigation works would not undergo much change and may be taken to be about 25 lakh acres. Adopting the proportions between upper plains and lower plains given by Madhya Pradesh in their Master Plan, it may be assumed that of the 25 lakh acres, 16 lakh acres will be in the upper plains and 9 lakh acres in the lower plains.

Water Depths (Delta)

7·7 Almost the whole area of the upper plains and a part of the lower plains consists of heavy black clayey soil which retains moisture and does not require very frequent irrigation. There is enough dampness in the soil after rainy season to make a paleo or preliminary watering prior to sowing unnecessary. Owing to good rainfall, irrigation of rice, perennials and other kharif crops would be completly unnecessary in the upper plains and to a considerable extent not required in the lower plains during the rainy months. Kharif crops sown for foodgrains such as jowar and maize will require only one watering if sown in advance of the rains and no watering thereafter except when rains fail. Kharif pulses and oilseeds do not usually require any irrigation. Wheat, barley and Rabi oil-seeds should not need more than 3 irrigations and may take less if winter rains are satisfactory. Rabi pulses, such as gram, will not take more than 2 waterings. Based on the above considerations, the depths at the field as indicated in Table 7·3 should be adequate to mature the various crops :—

TABLE 7·3

Depths of water required for maturing crops in Madhya Pradesh

Serial No.	Crop		Depth of waterings at field for areas in—	
			Upper Plains (Average annual rainfall 52″)	Lower Plains (Average annual rainfall 30″)
1	Rice	..	24	30
2	Other Kharif	..	6	9
3	Wheat	..	9	12
4	Other Rabi	..	9	12
5	Cotton	..	No area	15
6	Perennials	..	48	60

NOTE—The above depth of waterings is exclusive of rainfall contribution

7·8 It has been calculated that with the above depths and crop patterns, the amount of water required at the canal head would be 4·2 MAF as per details given in Table 7·4

TABLE 7·4

Water Requirements for Major Projects in Madhya Pradesh

Sl. No.	Zone	Crop	Area irrigated (lakh acres)	Delta at field (inches)	Water requirements in field (MAF)	Transit losses @ 50 per cent of Col. 6	Water requirements at canal head (MAF)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
1	Upper plains ..	Rice	2·4	24	0·48	0·24	0·72	
		Other Kharif	3·2	6	0·16	0·08	0·24	
		Wheat ..	6·4	9	0·48	0·24	0·72	
		Other rabi ..	3·2	9	0·24	0·12	0·36	
		Perennials ..	0·8	48	0·32	0·16	0·48	2·52
2	Lower plains	Rice ..	0·45	30	0·12	0·06	0·18	
		Other Kharif ..	3·15	9	0·24	0·12	0·36	
		Wheat ..	2·25	12	0·22	0·11	0·33	
		Other rabi ..	0·45	12	0·05	0·02	0·07	
		Cotton ..	2·25	15	0·28	0·14	0·42	
		Perennials ..	0·45	60	0·22	0·11	0·33	1·68
		Total ..	25·00 lakh acres				4·2	MAF
					Evaporation losses in reservoirs		1·8	MAF
						Total	6·0	MAF

The maximum area irrigated by any of the projects given in Table 7·1 is about 7·5 lakh acres. The provision of 50 per cent for losses for a canal system of this size situated in clayey soil should be adequate.

The above gives an overall delta of 2·4 feet per acre (exclusive of rainfall contribution) for *major projects.*

Medium and Minor Projects

7·9 As the total area expected to be irrigated is 65 lakh acres of which 25 lakh acres will go under major projects, the balance to be done by medium and minor works would be about 40 lakh acres.

7·10 Conditions on medium and minor works are different from those of major works. In the case of former, irrigation is done mainly in the winter season to avoid heavy losses in reservoir during the hot weather and the large wastage which would occur in irrigating scattered areas of early kharif or perennials. Such works should, therefore, irrigate rabi and rice only in the upper hilly areas and rabi alone elsewhere. As some area will have to be left for cultivation of kharif crops, such as jowar, maize, kharif pulses and oil-seeds, the area to which water can be applied may be taken to be 40 per cent rice and 25 per cent rabi for upper hilly areas and 75 per cent rabi only for other areas. Of the 40 lakh acres, to which facilities for irrigation will be provided by medium and minor works, 8 lakh acres may be regarded as lying in upper hilly areas according to proportion given in the Master Plan and 32 lakh acres in other areas.

7·11 It has been calculated that the quantity of water required for medium and minor works on the above considerations would be as given in Table 7·5.

TABLE 7·5

Water Requirements for Medium/Minor Irrigation works in Madhya Pradesh

Sl. No.	Zone	Crop	Area irrigated (lakh acres)	Delta at field (inches)	Water requirements at field (MAF)	Transit losses at 30 per cent of Col. 6	Water requirements at canal head (MAF)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Upper hilly areas	Rice	3·2	24	0·64	0·21	0·85
		Rabi ..	2·0	9	0·15	0·05	0·20
2	Other areas	Rabi ..	24·0	9	1·80	0·60	2·40
		Total ..	29·20				3·45

This gives a delta of 1·18 ft. per acre at the canal head (exclusive of rainfall contribution)

7·12. In view, however, of the acute shortage of food and the necessity of raising the living standards, the areas particularly under medium irrigation projects, have to be developed on lines somewhat similar to those of major projects.

To allow for such a contingency, the Committee feel that the overall delta for these 40 lakh acres under medium and minor works should be kept about the same as that for 25 lakh acres under major irrigation projects.

Overall Delta

7·13 The overall delta for 25 lakh acres under major projects works out to 2·4 ft. (Para. 7·8 above). For the 40 lakh acres under medium and minor works, the same delta of 2·4 ft. recommended in Para. 7·12 above would give the total requirements of major, medium and minor works as 15·6 MAF. This includes evaporation loss of 1·8 MAF in the reservoirs of the main river as also in the medium and minor tanks. Madhya Pradesh will, however, have unrestricted use of water for their projects except in years of poor rainfall when sharing of stored supplies will have to be done as discussed in Para. 7·24.

Maharashtra

7·14 Maharashtra have indicated their requirement for irrigation as 0·1 MAF (Chapter VI, Para. 6·49). This is comparatively insignificant and can be conveniently had without affecting the utilisation in other States.

Gujarat

7·15 The gross area commanded by the RL+300 canal in Gujarat State is 87·66 lakh acres, of which 66·51 lakh acres is culturable. These figures exclude the areas of the Great Rann of Kutch and also the area formerly intended to be irrigated by the Mahi Canal but now proposed to be transferred to the Narmada Canal from which it can be conveniently served. According to the memorandum received from the Gujarat Government, they propose to provide water for irrigation to 34·74 lakh acres excluding Mahi area and the Great Rann of Kutch. If 6·57 lakh acres is added for Mahi and 4·5 lakh acres for Great Rann of Kutch, the total becomes 45·81 lakh acres.

7·16 The existing crop pattern in the tract to be served by the Narmada Canal, the crop pattern proposed by the Gujarat Government and that recommended by the Committee are given in Table 7·6.

TABLE 7·6

Existing and proposed crop pattern in Gujarat

Sl. No.	Zone	District	Mean annual rain-fall (inches)	Crop	Crop pattern as		
					Existing (average of 1956—61) per cent of net area sown	Proposed by Gujarat	Recommended by the Committee
						Per cent of irrigated area	
1.	Area under L. L. C. and zones I, II & III	Broach & Baroda	31·7	Rice ..	9·8	25	15
				Kharif cereal ..	19·9	5	10
				Kharif oilseeds (including G. nut).	4·1	..	5
				Wheat and other rabi.	4·6	26	10
				Cotton ..	46·8	27	45
				Tobacco ..	1·7	1·5	...
				Fodder ..	7·5	3	10
				Perennials ..	0·6	7·5	5

Sl. No.	Zone	District	Mean annual rain-fall (inches)	Crop	Crop pattern as		
					Existing (average of 1956—61) per cent of net area sown	Proposed by Gujarat	Recommended by the Committee
						Per cent of irrigated area	
2.	IV	Kaira ..	32·0	Rice ..	13·9	30	15
				Kharif cereal ..	31·9	10	25
				Kharif oilseeds (including G. nut).	7·7	8	10
				Wheat and other rabi.	15·6	38	10
				Cotton ..	12·2	25	15
				Tobacco ..	11·1	5	5
				Fodder ..	10·1	5	15
				Perennials ..	1·1	8	5
3.	V, VI, VII, VIII, IX, & XI.	Ahmedabad and Surendranagar (larger part of the area lies in these two districts).	22·0	Rice ..	2·5	15	5
				Kharif cereals ..	32·6	15	15
				Kharif oilseeds (including G. nut).	4·5	10	10
				Wheat and other rabi.	13·4	47	25
				Cotton ..	38·9	30	30
				Tobacco ..	0·1	..	..
				Fodder ..	5·4	8	10
				Perennials ..	0·3	2	5
4.	X ..	Banaskantha ..	20·0	Rice ..	0·2	..	..
				Kharif cereals ..	65·4	30	40
				Kharif oilseeds (including G. nut).	7·1	15	15
				Wheat and other rabi.	14·8	60	25
				Cotton ..	1·2	10	10
				Fodder ..	12·7	..	10
				Perennials ..	0·4	8	..
5,	Little and Great Rann of Kutch.	Kutch ..	10·0	Rice ..	..	40	35
				Kharif cereals ..	40	20	20
				Kharif oilseeds(including G. nut).	5·7	10	10
				Wheat and other rabi.	2·2	50	15
				Cotton ..	12·3	20	10
				Fodder ..	17·7	15	10
				Perennials ..	1·2	10	..

Water Depths (Delta)

7·17 The rainfall and climate in Gujarat vary considerably in the commanded area. The lands near the coast get more rain and the climate is not so cold as in areas further north where the rainfall drops to as little as 10″ to 15″. The soil also changes from heavy black clayey in Broach and Baroda to loam and light loam in the lower portion of the canal. The quantity of water required for maturing crops would, in the circumstances, be somewhat greater than that needed in Madhya Pradesh. Some of the kharif cereals and oilseeds may, in parts of Gujarat State, have to be given irrigation in the monsoon periods also owing to poor rainfall. The number of waterings for wheat and other rabi crops would also be greater. Taking the above remarks into consideration, the overall water depths at the field proposed by the Committee for Navagam Canal in Gujarat are given in Table 7·7.

TABLE 7·7

Depths of water required for watering crops in Gujarat

Sl. No.	Crop	Depth of waterings at field in	
		Areas other than Rann (Average annual rainfall 25·5″)	Little Rann and Great Rann of Kutch (Average annual rainfall 10″)
1.	Rice ..	30	42
2.	Kharif cereal	9	12
3.	Wheat and other rabi ..	15	15
4.	Tobacco ..	24	No area
5.	Cotton ..	18	24
6.	Fodder ..	12	15
7.	Perennials ..	60	No area

NOTE—The above depths of waterings is exclusive of rainfall contribution.

7·18 The quantity of water required for areas to be irrigated in Gujarat with the above depths has been calculated to be 7·12 MAF at the field *vide* Table 7·8.

TABLE 7·8

Water requirements for areas in Gujarat

Sl. No.	Zone	Crop	Area in lakh acres	Delta at field (inches)	Water requirements at field	Transit losses at 50 per cent of Col. 6	Water requirements at canal head
					MAF		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Areas other than Rann of Kutch.	Rice ..	3·61	30	0·90	0·45	1·35
		Khairf cereal and oil-seeds	10·11	9	0·75	0·37	1·12
		Wheat and other rabi	6·81	15	0·85	0·42	1·27
		Cotton ..	11·44	18	1·72	0·86	2·58
		Tobacco ..	0·37	24	0·07	0·03	0·10
		Fodder ..	4·20	12	0·42	0·21	0·63
		Perennials ..	1·77	60	0·88	0·44	1·32
2.	Little and Great Rann of Kutch.	Rice ..	2·62	42	0·92	0·46	1·38
		Kharif cereal and oil-seeds.	2·26	12	0·23	0·11	0·34
		Wheat and other rabi	1·12	15	0·14	0·07	0·21
		Cotton ..	0·75	24	0·15	0·07	0·22
		Fodder ..	0·75	15	0·09	0·04	0·13
		Total ..	45·81 lakh acres		7·12 MAF		10·65 MAF

Adding 50 per cent for transit losses, the total comes to 10·65 MAF at the canal head. As the main canal will be lined, the losses would be greatly reduced and provision of 50 per cent should, in the circumstances, be adequate. Allowing one million acre feet for evaporation losses in the Navagam reservoir, the total would be 11·65 MAF. This gives an overall delta of 2·50 ft. per acre (exclusive of rainfall contribution).

Overall Delta

7.19 While 2·50 ft. delta (exclusive of rainfall contribution) would be fully justified in case of Gujarat against 2·4 ft. for Madhya Pradesh because of the greater rainfall in the latter State, there are other factors which have to be taken into consideration in fixing the optimum figure.

In the early stages of irrigation development in Madhya Pradesh, there will be enough water for Gujarat placing no limitation on the depth of water on its fields. But when irrigation fully develops in Madhya Pradesh, there will be need for sharing, particularly in bad years. Because of hilly terrain and steeper slopes even in the plain areas, there will be better drainage and lesser build-up of the subsoil water reservoir in Madhya Pradesh. In Gujarat, on the other hand, with greater development of irrigation and very much flatter slopes of the areas under command, the subsoil water table will rise considerably and if not checked in time, may lead to waterlogging. This subsoil water can be usefully employed for irrigation by means of pumping. That will cut down the need for too liberal supplies of canal water for irrigation.

The Committee, therefore, feel that the overall delta for Gujarat areas should be kept the same as for Madhya Pradesh, namely, 2·4 feet.

On this basis, the total water requirement for Gujarat areas from the Navagam canal will be:

$45{\cdot}8 \times 2{\cdot}4 = 10{\cdot}99$ MAF

Deducting the likely inflows into the Navagam canal from the minor streams crossing it in its course (Para. 8·3 Chapter VIII), the net utilisation for the canal from the Narmada river will be $10{\cdot}99 - 0{\cdot}34 = 10{\cdot}65$ MAF. This includes evaporation losses of 1·0 MAF in the Navagam reservoir.

Rajasthan

7·20 The gross area of Rajasthan State commanded by flow by the Navagam +300 canal is between 1·5 and 2 lakh acres and the actual irrigation may be taken to be about 1 lakh acres. As rainfall here is almost entirely absent, all crops would have to be matured by artificial irrigation and overall depth of 2·5 feet at the canal head based on the analogy of the Rajasthan canal, which is a very long system running through desert area, may be taken for Rajasthan lands irrigated by Narmada. The quantity of water required for this would be 0·25 million acre feet.

General

7·21 The total demand for the four States as accepted by the Committee thus comes to:—

Madhya Pradesh	..	15·60 MAF
Maharashtra	..	0·10 MAF
Gujarat	..	10·65 MAF
Rajasthan	..	0·25 MAF
Total		26·60 MAF

This, according to the runoff figures compiled by the Central Water and Power Commission, is available in 40 years out of 48 years between 1915—1962 without carryover and in 44 out of 48 years with carryover.

7·22 It would thus be seen that Narmada carries adequate water to meet all demands for irrigation calculated on a realistic basis.

7·23 According to the calculations given in the previous paragraphs, the amount of water required by Madhya Pradesh and Maharashtra in a full year is 13·9 MAF excluding 1·8 MAF loss in the reservoirs of the main river. For Gujarat and Rajasthan, the corresponding amount is 9·9 MAF excluding losses in the Navagam reservoir. Tables 7·9 and 7·10 show the expected monthly withdrawals for Madhya Pradesh and Maharasthra and for Gujarat and Rajasthan, respectively.

TABLE 7·9

Monthly withdrawals for Irrigation in Madhya Pradesh and Maharashtra

Sl. No.	Month	Major and medium projects (57 lakh acres)	Minor irrigation works (8 lakh acres)	Total for Madhya Pradesh	Maharashtra (0·1 lakh acres)
		MAF			
1.	January ..	1·42	0·22	1·64	0·005
2.	February ..	0·20	0·04	0·24	0·005
3.	March ..	0·26	0·05	0·31	0·005
4.	April ..	0·48	0·08	0·56	0·005
5.	May ..	1·00	0·18	1·18	0·010
6.	June ..	1·18	0·19	1·37	0·015
7.	July ..	0·63	0·10	0·73	0·010
8.	August ..	0.84	0·14	0·98	0·005
9.	September ..	1·77	0·28	2·05	0·010
10.	October ..	0·92	0·16	1·08	0·010
11.	November ..	1·59	0·24	1·83	0·010
12.	December ..	1.59	0·24	1·83	0·010
	Total ..	11·88	1·92	13·80	0·100

TABLE 7·10

Monthly withdrawals for Irrigation in Gujarat and Rajasthan

Sl. No.	Month	Gujarat (45·81 lakh acres) MAF	Rajasthan (1 lakh acres) MAF	Total
1.	January ..	0·46	0·015	0·475
2.	February ..	0·13	0·005	0·135
3.	March ..	0·30	0·015	0·315
4.	April ..	0·41	0·015	0·425
5.	May ..	0·80	0·020	0·820
6,	June ..	1·50	0·035	1·535
7.	July ..	1·36	0·030	1·390
8.	August ..	0·48	0·015	0·495
9.	September ..	1·15	0·030	1·180
10.	October ..	1·13	0·030	1·160
11.	November ..	0·96	0·020	0·980
12.	December ..	0·97	0·020	0·990
	Total	9·65	0·250	9·900

Sharing of Waters

7·24 It would be seen from these that the quantity of water required in the monsoon months of July, August and September is 3·78 MAF for Madhya Pradesh and Maharashtra and 3·06 MAF for Gujarat and Rajasthan. The requirements of the States for the nine dry months, i. e., from 1st October to 30th June will, therefore, be 10·12 MAF for Madhya Pradesh and Maharashtra and 6·83 MAF for Gujarat and Rajasthan or a total of 16·95 MAF for all the four States. Some flow continues in the Narmada in the dry period also and overall addition to reservoir capacity excluding reservoir losses on this account may be taken at about 1·0 MAF.

If, therefore, there is a total storage of 15·95 MAF, say 16·0 MAF or more on the 1st October in the reservoirs, major, medium and minor put together, there would be enough to meet all needs for irrigation and no question of sharing would arise.

If, however, in any year the quantity is less than 16·0 MAF, the available water would have to be shared between the two States in the ratio of 10·12 : 6·83 or approximately 3 : 2.

7·25 The Committee, however, feel that it will be extremely difficult to estimate the storage in the large number of small and scattered minor irrigation works with any degree of accuracy and it would, therefore, be desirable to exclude these works and the area irrigated by them in working out the proportions in which water is to be shared. As projects under medium and minor works have still to be prepared by Madhya Pradesh, it is not possible to say precisely how much area will be irrigated by minor and how much by medium works. But it can be assumed that most of the irrigation will be from medium works and minor works are not likely to do more than 20 per cent of the total or say 8 lakh out of the 40 lakh acres.

7·26 According to the overall delta of 2·4 ft., the quantity of water required for 8 lakh acres under minor works would be 1·92 MAF. The net demand for Madhya Pradesh and Maharashtra for major and medium projects would then become (13·90—1·92=) 11·98 MAF for the whole year and 8·72 MAF for the nine dry months.

7·27 The total requirements of medium and minor works on the Narmada system would thus become 15·55 MAF for the nine dry months. Deducting 1·0 MAF for net addition from river flow in this period, this would become 14·55 MAF, say 14·5 MAF, when sharing should start. According to this proposal, the ratios in which water is to be shared would be 8·72 : 6·83 or nearly 4 : 3.

The position of Irrigation and Power in cycles of bad years on full development of irrigation with sharing as above may be seen in Annexure VII-1.

Navagam Canal to be constructed as one unit

7·28 Gujarat State should construct the entire canal system as one unit and not in various stages so that in the early years when irrigation in Madhya Pradesh is being developed, they may be able to draw larger quantities of water needed for reclamation of lands in the two Ranns of Kutch and for improving saline areas elsewhere in the State. It would be advisable to finish reclamation before supplies get reduced and are no longer surplus to actual crop irrigation requirements.

7·29 Also, it is most important that irrigation should be extended to the border areas with Pakistan both in Gujarat (Great Rann of Kutch) and Rajasthan (Barmer desert) at the earliest possible date so that peasantry can be permanently settled there.

7·30 Another reason for taking up the project as one is to expedite the navigation facilities which will become available from tail to head of Navagam canal and on to Navagam reservoir and also between Kandala port, the Navagam canal and the Navagam reservoir.

Subsoil Water Reservoirs, Waterlogging and Drainage

7·31 With the introduction of large-scale irrigation both in Madhya Pradesh and in Gujarat, substantial quantities of water will be stored up in subsoil reservoirs in addition to what may go back into the river as regeneration. This will raise the subsoil water level to varying depths below the surface, depending upon topography and land use, leading to waterlogging in the low lying areas and to adverse effects in the root zone of crops even in areas somewhat higher up if the subsoil water level rises to this zone. Such conditions of waterlogging

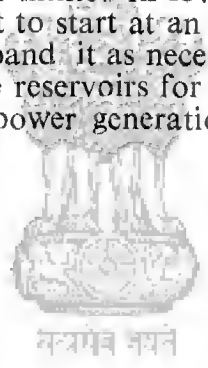
have occurred in most irrigation projects, more particularly in Enst Punjab (India) and Pakistan. It will be necessary to keep subsoil water levels in the plain areas within safe limits for crop production. For that it will be desirable to undertake supplementary irrigation by pumping, almost simultaneously with flow irrigation.

The subsoil reservoirs, both in Madhya Pradesh and Gujarat, particularly the latter, will provide substantial subsoil storages to supplement the surface storages. These subsoil storages have the advantage that in their case there will be no evaporation loss.

7·32 It is desirable that along with introduction of canal irrigation, the natural drainages of the commanded area should be improved and care taken to see that no obstructions are placed in them by cultivators or others. Where accumulations of water or badly drained pockets exist, artificial cuts should be made to remove excess water and prevent damage to land due to rise in spring level after the coming of the canal.

These notwithstanding, the subsoil water levels will gradually rise, leading to waterlogging of progressively more areas.

To obviate the necessity for a costly and extensive network of drainages, the effect of which will at best be limited in lowering the water table, locally to bed levels of drains, it will be best to start at an early stage a network of pumping installations for irrigation and expand it as necessity arises. This will also help to conserve supplies stored in surface reservoirs for use elsewhere both for extension of areas to be irrigated and for power generation.



ANNEXURE VII-1

IRRIGATION AND POWER IN CYCLES OF BAD YEARS AT FULL DEVELOPMENT OF IRRIGATION

I. CYCLE 1917—18—19

1917 is a good year with 49·15 MAF runoff followed by 1918 which is a bad year with 14·07 MAF runoff.

		MAF		MAF
At the end of October 1917 all the reservoirs will be full giving a total storage of	..	28·22	=	28·22
Runoff in November, December, 1917	..	2·07		
Runoff till September, 1918	..	12·08		14·15
		14·15		42·37
Total water available	..			
Waters used for *irrigation* November to September				
Madhya Pradesh	..	10·96*		
Water stored in minor schemes in Madhya Pradesh	..	1·92		
Maharashtra	..	0·10		
Gujarat	..	8·52*		
Rajasthan	..	0·22*		
			21·72	
Water used for *power*				
From Navagam river bed power house from November to September		3·58@		
Evaporation losses	..	2·50		
			6·08	
				27·80
Waters available in storages in Madhya Pradesh and Navagam on the 1st October, 1918	..			14·57

Navagam water account		MAF		
Effective storage at the end of October, 1917	..	11·22		
Runoff in November, December, 1917	..	0·40		
Runoff till September, 1918	..	0·85		
Regulated releases from Barwaha from November, 1917 to September, 1918	..	6·87†		
Total water November, 1917 to September, 1918	..	..		19·34

* Refer to the monthly irrigation abstraction tables 7·9 and 7·10 in Chapter VII.

@ *See* Table No. XII—2(D) in Annexure to Chapter XII.

† Annual release from Barwaha = 7·5 MAF

release for 11 months $= 7{\cdot}5 \times \frac{11}{12} = 6{\cdot}87$

[Refer to table XII—2(E) in Annexure to Chapter XII]

		MAF	MAF
			19·34
Waters used for *irrigation* from November 1917 to September 1918 for Gujarat and Rajasthan as already mentioned above	..	8·74	
Waters used for *power* as already mentioned above	..	3·58	
Evaporation losses in Navagam reservoir	..	1·00	
Total water used up	..	13·32	13·32
Waters available in Navagam reservoir on 1st October, 1918	..		6·02
Waters available in Punasa and upstream reservoirs on 1st October, 1918=14·57—6·02	..		8·5

The total available storage on 1st October 1918 is above 14·5 MAF, but the storage at Navagam is below 6·20. Therefore, Madhya Pradesh will have to release 0·18 MAF to make up the deficit of storage at Navagam reservior as discussed in Chapter VII, Para. 7·26.

Power production in year 1918—1919

(*a*) **Madhya Pradesh**		MAF	MAF
Storage available on 1st October, 1918	..	8·55	
Runoff in October, November and December, 1918	..	1·85	
Runoff from January to June, 1919	..	1·60	
Total water available	..	12·00	12·00
Irrigation withdrawal (October 1918 to June, 1919)	..	8·64	
Evaporation losses	..	1·50	
		10·14	10·14
Release from Barwaha, the last reservoir in Madhya Pradesh			1·86
Release from Punasa to Barwaha=1·86+2·20 (Irrigation requirement of Barwaha—October to June)	..		4·06
Power generated at Punasa	=163 MW@ 60% L.F.		
Power generated at Barwaha	= 45 MW@ 60% L.F.		
Total power (Punasa+Barwaha)	=208 MW@ 60% L.F.		

(The release from Madhya Pradesh, viz., 1·86 MAF is more than required for Gujarat, i.e., 0·18 MAF. Thus in their own interest Madhya Pradesh would have released more water than that needed to make up Gujarat share.)

(*b*) **Navagam**		MAF	MAF
Storage available on 1st October 1918	=	6·02	
Runoff in October, November, December, 1918		0·15	
Runoff from January to June, 1919	=	0·40	
Release from Barwaha	=	1·86	
Total water available		8·43	8·34

		MAF	MAF
Irrigation withdrawal (October to June)	=	6·83	
Evaporation losses	=	0·50	
		7·33	7·33
Water used in river bed power house	=		1·10
Power generated in river bed with 1·10 MAF	=	88 MW	
Water used in canal power house—6·83 MAF			
Power generated in canal power house	=	228 MW	
Total power at Navagam	=	316 MW @ 60% L.F.	
Total power generated at Punasa, Barwaha and Navagam during October, 1918 to June, 1919	=	208+316=524 MW @ 60 L.F.	

(It may be mentioned that full amount of power (982 MW @ 60% L. F.) was generated during three monsoon months, i e., July to September, 1918).

Next Year 1919

Runoff during July, August, September, 1919 is 41·75 MAF, which will fill up all the reservoirs after utilising waters for the normal requirements of irrigation and power during these months. On and from the 1st October 1919, the position is satisfactory.

II—CYCLE 1940-41-42

1940 is a good year with 38·18 MAF runoff followed by 1941 which is a bad year with 15·95 MAF.

At the end of October, 1940, *all the reservoirs* will be full giving a total storage of 28·22 MAF.

		MAF	MAF
Runoff in November, December, 1940	=	1·59	
Runoff from January to September, 1941	=	13·69	
		15·28	15·28
			28·22
Total water available	=		43·50
Waters used for *irrigation* from November to September in all the States as given in the previous case.		21·72	
Waters used for *power* from Navagam river bed power house from November to September as given in the previous case.		3·58	
Evaporation losses	=	2·50	
Total waters used up	=	27·80	27·80
Waters available in storages in Madhya Pradesh and Navagam on the 1st October 1941.		=	15·70

		MAF	
Navagam			
Effective storage at the end of October, 1940	=	11·22	
Runoff in November, December, 1940	=	0·32	
Runoff from January to September, 1941	=	3·38	
Regulated releases from Barwaha, November, 1940 to September 1941.	=	6·87	
Total waters available	..	21·79	21·79
Total waters used up for irrigation, power and evaporation from November, 1940 to September, 1941 as mentioned in the previous case.			13·32
Waters available in Navagam reservoir on the 1st October, 1941			8·47
Waters available in Punasa and upstream reservoirs on the 1st October, 1941.			7·23
Total storage in all reservoirs			15·70

Total storage is more than 14·5 MAF and Navagam has more than 6·20 MAF of storage. Therefore the question of sharing does not arise in this case, though this is a deficit year.

Power production in 1941-42

Madhya Pradesh	MAF	MAF
Storage available on the 1st October, 1941	= 7·23	
Runoff in October, November, December, 1941	= 1·70	
Runoff from January to June, 1942	= 1·52	
Total water available	10·45	10·45
Irrigation withdrawals (October to June)	= 8·64	
Evaporation losses	= 1·50	
	10·14	10·14
Therefore release from Barwaha (the last reservoir in Madhya Pradesh).		= 0·31
Release from Punasa to Barwaha as explained in the previous case		= 2·20
Total release from Punasa		2·51
Power generated at Punasa	= 101 MW @ 60 per cent L.F.	
Power generated at Barwaha	= 8 MW @ 60 per cent L.F.	
Total in Madhya Pradesh	109 MW @ 60 per cent L.F.	

Navagam		MAF	MAF
Storage available on the 1st October, 1941	=	8·47	
Runoff in October, November, December, 1941	=	0·56	
Runoff from January to June, 1942	=	0·37	
Release from Barwaha	=	0·31	
Total water available	=	9·71	9·71
Irrigation withdrawal (October to June)	=	6·83	
Evaporation losses	=	0·50	
Total waters used up	=	7·33	7·33
Water used in river bed power house	=		2·38
Power generated in river bed power house	=	191 MW at 60% L.F.	
Water used in canal power house	=	6·83 MAF	
Power generated in canal power house	=	228 MW at 60% L.F.	
Total power at Navagam	..	419 MW at 60% L.F.	
Total power generated at Punasa, Barwaha and Navagam	=	109+419=528 MW at 60% L.F.	

[It may be mentioned that full amount of power (982 MW at 60 per cent L.F.) was generated during the three monsoon months, viz., July to September, 1941.]

Next year 1942

Runoff during July, August and September, 1942 is 35·37 MAF, which will fill up all the reservoirs after utilising waters for the normal requirements of irrigation and power during these months.

Thus the position is satisfactory on and from the 1st October, 1942.

III. CYCLE 1950-51-52-53-54

1950 is a good year with 30·79 MAF runoff followed by 1951 which is a bad year with 18·32 MAF runoff, followed by 1952 which is again a bad year with 19·11 MAF, runoff followed by 1953 which is a sub-normal year with 23·97 MAF runoff.

At the end of October, 1950, *all the reservoirs* will be full giving a total storage of 28·22 MAF

		MAF	MAF
Runoff in November, December, 1950	=	1·29	
Runoff from January to September, 1951	=	15·73	17·02
			28·22
Total water avialable	=		45·24

		MAF	MAF
Waters used for irrigation from November, 1950 to September, 1951 in all the States as given in the earlier cases.	=	21·72	
Waters used for power from Navagam river bed power-house from November, 1950 to September 1951 as given in the earlier cases.	=	3·58	
Evaporation losses	=	2·50	
Total waters used up			27·80
Waters available in storages in Madhya Pradesh and Navagam on the 1st October, 1951.			17·44

Navagam

Effective storage at the end of October, 1950	=	11·22
Runoff in November, December, 1950	=	0·29
Runoff from January to September, 1951	=	2·58
Regulated releases from Barwaha from November, 1950 to September, 1951.	=	6·87
Total water available	=	20·96
Total waters used up for irrigation, power and evaporation from November to September as mentioned in previous cases.	=	13·32
Waters available in Navagam reservoir on the 1st October, 1951	=	7·64
Waters available in Punasa and upstream reservoirs on 1st October, 1951 (17·44—7·64).	=	9·80

Total storage is more than 14-5 MAF and Navagam has more than 6-2 MAF of storage. Therefore, the question of sharing does not arise in this case, though this is a deficit year.

Power production in year 1951-52

Madhya Pradesh

		MAF	MAF
Storage available on 1st October, 1951	=	9·80	
Runoff in October, November, December, 1951	=	2·16	
Runoff from January to June, 1952	=	0·70	
Total water available	=		12·66
Irrigation withdrawals (October, 1951 to June, 1952)	=	8·64	
Evaporation losses	=	1·50	
Total waters used up			10·14
Thus, the release from Barwaha, the last reservoir in Madhya Pradesh	=		2·52
Release from Punasa to Barwaha as explained earlier (2·52+2·22)	=	4·74	
Power generated at Punasa	=	201 MW at 60% L. F.	
Power generated at Barwaha	=	61 MW at 60% L. F.	
Total power in Madhya Pradesh	=	262 MW at 60% L. F.	

Navagam

Storage available on 1st October 1951	= 7·64 MAF	
Runoff in October, November, December 1951	= 0·43 MAF	
Runoff from January to June 1952	= 0·10 MAF	
Release from Barwaha	= 2·52 MAF	
Total waters available	= 10·69	10·69
Irrigation withdrawal (October—June)	= 6·83	
Evaporation losses	= 0·50	
Total waters used up	=	7·33
Water used in river bed power house 10·69—7·33	=	3·36
Power generated in river bed power house	= 268 MW at 60% L.F.	
Water used in canal power house	= 6·83 MAF	
Power generated in canal power house	= 228 MW at 60% L.F.	
Total power at Navagam	= 496 MW at 60% L.F.	
Total power generated at Punasa, Barwaha and Navagam 262+496	= 758 MW at 60% L.F.	

Checking position of storages on 1st October 1952, which again is a deficit year

Storage on the 1st July 1952	= 0·00 MAF	
Runoff in July, August, September 1952 (Madhya Pradesh 13·50+ Navagam 2·11)	15·61 MAF	
	15·61	

Madhya Pradesh

Inflow		= 13·50 MAF	
Irrigation (Major and Medium projects)	= 3·25		
Storage under minor irrigation works	= 1·92		
Evaporation	= 0·50		
	5·67	5·67	
Net available in Madhya Pradesh storage on 1st October 1952		= 7·83 MAF	

Navagam

Inflow = 2·11 MAF

Irrigation requirements are 3·06 MAF, which are more than the available inflow. Thus irrigation suffers in Gujarat during the rainy season as Madhya Pradesh cannot let down any waters before 1st October 1952.

Power during monsoon — July, August, September 1952

Madhya Pradesh

Punasa and Barwaha will not release any water as reservoirs are partially full and Madhya Pradesh would prefer to preserve it for irrigation in post monsoon months.

In Gujarat power will be generated at canal power house which would be about 160 MW as head will be very small.

On 1st October, 1952

		MAF
Storage in Madhya Pradesh reservoir	=	7·83
Storage in Navagam	=	0·00

Therefore Madhya Pradesh has to release 7·83 × 3/7 = 3·36 MAF of waters to Gujarat

Power and Irrigation position in this year, 1952-53 during Post Monsoon Months—

Madhya Pradesh

			MAF
Storage on 1st October 1952	(7·83—3·36 =)		4·47
Runoff in October, November, and December 1952		=	2·40
Runoff from January to June 1953		=	0·80
			7·67
Evaporation losses		=	1·00
Net water available		=	6·67

Irrigation requirement in Madhya Pradesh during October, 1952 to June, 1953 is 8·64 MAF which is more than the available storage of 6·67 MAF. Irrigation suffers by about 2·0 MAF.

About 1 MAF may be released below Punasa for irrigation at Barwaha, Punasa has also to release 3·36 MAF for Gujarat.

Power at Punasa	=	112 MW at 60% L. F.
Power at Barwaha	=	65 MW at 60% L. F.
Total	=	177 MW at 60% L. F.

Navagam

		MAF
Storage on the 1st October 1952	=	3·36
Runoff in October, November, December 1952	=	0·30
Runoff from January to June 1953	=	0·20
		3·86
Evaporation losses	=	0·30
Total water available	=	3·56

Irrigation requirements in Gujarat and Rajasthan during October—June is 6·83 MAF, which is more than 3·56 MAF. Irrigation suffers by about 3 MAF.

Power at canal power house will be = 61 MW at 60% L. F.

Total power at Punasa, Barwaha and Navagam = 177 + 61 = 238 MW at 60% L. F.

Checking position of storages on the 1st October 1953 which is again a sub-normal year—

Storage on the 1st October 1953	=	0·00 MAF
Runoff in July, August, September 1953 (Madhya Pradesh 15·33 MAF + Navagam 4·25 MAF)	=	19·58

Madhya Pradesh

Inflow July, August, September		=	15·33 MAF
Irrigation use Major—medium	=	3·25	
Minor Irrigation storage	=	1·92	
Evaporation	=	0·20	
			5·37
Net water available in Madhya Pradesh storages on the 1st October 1953		=	9·96

Navagam

Inflow (July, August, September 1953)		=	4·25 MAF
Irrigation use	=	3·06	
Evaporation losses	=	0·20	
		=	3·26

Net water available at Navagam reservoir on the 1st October 1953 = 0·99 MAF

Power during monsoon months i. e., July, August, September 1953

Madhya Pradesh

Punasa and Barwaha will not release any water for irrigation or power as reservoirs would be partially full and Madhya Pradesh would prefer to preserve it for irrigation in post monsoon months.

Navagam

Power will be generated at canal power house which will be 172 MW at 60 per cent L. F.

Position on the 1st October 1953

		MAF
Storage in Madhya Pradesh	=	9·96
Storage in Navagam	=	0·99
Total storage	=	10·95

Share of Madhya Pradesh = 10·95 × 4/7 = 7·26 MAF. Therefore, Madhya Pradesh has to release 10·15 — 7·26 = 3·69 MAF of waters to Gujarat, making up their storage to 0·99 + 3·69 = 4·68 MAF. which is their share.

Power and irrigation position in this period

Madhya Pradesh		MAF
Storage on the 1st October 1953	..	= 7·26
Runoff in October, November, December 1953	..	= 2·65
Runoff from January to June 1954	..	= 1·00
Total water available	..	10·91

Irrigation requirements of Madhya Pradesh during October—June are 8·64 MAF and evaporation losses will be about 1·0 MAF. Thus, irrigation demand will be fully met and there will be a release of 1·27 MAF of water from Barwaha power house.

Power in Madhya Pradesh

Punasa release—3·69 + 2·20 + 1·27 = 7·16 MAF		
Power	=	285 MW at 60% L. F.
Barwaha release—3·69 + 1·27 = 4·96 MAF		
Power	=	116 MW at 60% L. F.
Total power in Madhya Pradesh	=	401 MW at 60% L. F.

Navagam

		MAF
Storage on the 1st October 1953	..	= 4·68
Runoff in October, November, December 1953	..	= 0·74
Runoff from January to June, 1954	..	= 0·43
Release from Barwaha	..	= 1·27
		7·12
Evaporation losses	..	= 0·50
Net water available		= 6·62

Irrigation requirement in Gujarat and Rajasthan is 6·83 MAF against 6·62 MAF available. Thus irrigation will suffer by about 0·21 MAF only.

Power at the canal	= 132 MW at 60% L. F.
Power from Punasa, Barwaha and Navagam	= 401 MW at 60% L. F.
Total for three stations	= 533 MW at 60% L. F.

transport (Plate IX-3). The Navagam canal has no falls from its offtake to its tail in Rajasthan, so that once traffic enters this canal, it can go north to Rajasthan and south and south-east into Gujarat and Madhya Pradesh.

9·10 The Committee did not have the material or the time to make even a skeleton plan for navigation facilities between Broach and Navagam or between Kandla, Navagam and Bargi.

On a very very rough estimate, the cost of providing navigation facilities in the form of lift weirs, locks, connecting channels, raising of bridges, etc., up to Bargi reservoir may be between 50 and 60 crores of rupees. Much detailed work both in field and office will have to be done to obtain anything approaching reasonably close figures of cost.

The designs of navigation works should be taken up simultaneously with the design of canals, regulators, dams, etc., so that both works can be taken up for construction at the same time. The cost of navigation works involved being relatively small compared with the cost of canal system, regulators and dams, it would be desirable to provide navigation facilities as soon as the navigable waterways become available for navigation.

Financing of navigation facilities

9·11 The cost of navigation facilities may be included in the estimate of the dams or other concerned structures and the revenue from navigation credited to the head to which the capital cost is charged.

9·12 It will perhaps be better if the Central Government (Ministry of Transport) assume full responsibility for the capital cost of such structures and share the revenues therefrom with the States on an agreed basis.

Checking position of storages on the 1st October 1954 which is an average year

Storage on the 1st July 1954 = 0·00MAF

Runoff in July, August, September, 1954 =28·18 MAF (M. P. 20·10 MAF+Nav. 8·08

Madhya Pradesh

		MAF
Irrigation use (Major-medium projects)	..	=3·25
Storage for minor irrigation works	..	=1·92
Evaporation	..	=0·50
	..	5·67

Storage on the 1st October 1964=20·10—5·57=14·43 MAF. This, with another 2·50 MAF inflow coming in October will bring to nearly the full storage capacity of all reservoirs which is 17·00 MAF.

Navagam

		MAF
Irrigation use	..	=3·06
Evaporation	..	=0·50
	..	3·56
Storage on the 1st October 1954 (8·08—3·56)	..	=4·52

Gujarat is entitled to minimum 6·20 MAF. The deficit of 1·68 MAF will be made good as there will be power releases from Madhya Pradesh.

Thus the position is quite satisfactory on the 1st October 1964

CHAPTER VIII

Water Resources of Mahi and other Rivers crossed by the Navagam Canal in Gujarat

8·1 At the request of the Committee, the Gujarat Government have sent a note in which they have given details of the rivers crossed by the Navagam canal in its passage through the State from Navagam dam and have indicated the use to which the waters are at present being put or are proposed to be put in the future. The main features of this note are given in the following paragraphs.

8·2 The proposed Navagam FSL+300 canal taking off from Navagam dam would cross serveral minor rivers before it reaches the northern boundary of Gujarat State. Details of these rivers are given in Table 8·1 (*See* also Plate VIII-1).

TABLE 8·1

Particulars of rivers crossed by Navagam Canal

Sl. No.	Name of river	Catchment area at the crossing (sq. miles)	Average rainfall (Inches)	Average runoff at canal crossing (MAF)	Possible utilisation by storages, etc. (MAF)	Proposed utilisation (MAF)	Balance available for Navagam canal (MAF)	Remarks
1	2	3	4	5	6	7	8	9
1	Heran ..	367	46	0·40	0·28	0·11	0·17	To be diverted to Navagam canal. Balance cannot be stored.
2	Orsang ..	645	51	0·52	0·34	0·17	0·17	To be diverted to Navagam canal. Balance cannot be stored.
	Total ..	1012	..	0·92	0·62	0·28	0·34	..
3	Dhadhar ..	90	41	0·14	0·14	0·14	..	..
4	Karad ..	180	43	0·13	..	..	..	Cannot be diverted for want of storage sites.
5	Goma ..	100	40	0·10	..	..	..	For want of suitable storage sites only a small amount may possibly be used by Minor works.

Sl. No.	Name of river	Catchment area at the crossing (Sq. miles)	Average rainfall (Inches)	Average runoff at canal crossing (MAF)	Possible utilisation by storages, etc. (MAF)	Proposed utilisation (MAF)	Balance available for Navagam canal (MAF)	Remarks
1	2	3	4	5	6	7	8	9
6	*Mahi* ..	11900	34	7·35	..	..	..	Utilisation discussed in para. 8·10 below.
7	Shedhi ..	186	34	0·05	0·05	0·05	..	..
8	Mahor ..	236	32	0·08	0·08	0·08	..	..
9	Watrak ..	1050	32	0·30	0·22	0·22	..	Cannot be diverted for want of storage sites.
10	Meshwa ..	560	30	0·22	0·06	0·06	..	Cannot be diverted for want of storage sites.
11	Khari ..	310	29	0·06	0·06	0·06	..	..
12	*Sabarmati* ..	5000	31	1·56	1·10	1·10	..	Balance cannot be utilised for want of storage sites. Some irrigation from Minor works may be possible if pick-up weir sites are found. Rajasthan State is considering possibility of storing water on tributaries of this river in their territory for power and irrigation.
13	Rupen ..	461	23	0·08	..	..	..	Cannot be utilised for want of suitable sites and also because water is saline.
14	Saraswati ..	700	24	0·23	0·10	0·10	..	The catchment is very flat and of sandy nature. Surplus water will, therefore, not be available for diversion.
15	*Banas* ..	2800	31	1·20	Not definitely known.	0·50	..	The available flows from un-intercepted catchment may be used for areas on the right bank where no alternative sources are available.

Rivers which are Tributaries of Narmada

8·3 The Navagam+300 canal will cross only two such rivers, namely: the Heran and the Orsang. The 75 per cent yield of the Heran is expected to be 0·23 MAF. There exists a pick-up weir for using the runoff of the river at Rajwasna for local irrigation and a dam upstream is being investigated. When this is constructed, it is hoped that 0·11 MAF would be utilised in areas commanded by the existing system and about 0·17 MAF which will be surplus to requirements would be available for augmenting supply in the Navagam+300 canal. The Orsang also has a weir existing at Jojwa for using the runoff of the river while two sites for storage, one on the main river and another on Sukhi, its tributary, are being investigated. When these are constructed, it would be possible to utilise about 0·34 MAF of which 0·17 MAF would be used in the areas served by dams themselves and the balance 0·17 MAF would be for diversion to Navgam canal.

Thus, between the Heran and Orsang, 0·17+0·17=0·34 MAF will be available for supplementing the Navagam canal supply.

Other Rivers

8·4 Beyond Orsang, the Navagam canal crosses 3 small rivers called Dhadhar, Karad and Goma, all originating in Gujarat. The resources of these are either already utilised in existing works or cannot be made use of owing to the absence of suitable storage sites.

Beyond the river Mahi which is dealt with later, the canal crosses the Mahor, Watrak, Meshwa and Khari, also originating in Gujarat, before reaching the Sabarmati. On all these rivers pick-up weirs and small storages to use the expected runoff are already existing or are being constructed or investigated. The storages with the resources which can be harnessed will be fully used in irrigating local areas and no surplus is likely to be available for augmenting the discharge of Navagam canal.

Sabarmati river

8·5 The Sabarmati river has a catchment area of 5,000 sq. miles above its junction with the proposed Navagam canal of which 1,950 sq. miles lie in Rajasthan. There is a pick-up weir on its tributary Hathmati which intercepts a catchment of 524 sq. miles, and a storage dam above the pick-up weir to make use of the probable runoff of this tributary is under construction. On the main Sabarmati river a storage dam is proposed at Dharoi, 95 miles north of Ahmedabad, to supply water for Ahmedabad city and the proposed new capital and to irrigate about 70,000 acres of high areas on the right bank of the river. The expected runoff above Dharoi is, therefore, likely to be fully used. It is not possible to use the inflow below Dharoi for irrigation as there are no storage sites. The run of the river will also be available for Ahmedabad water supply.

The Rajasthan Government are considering the possibility of constructing storage reservoirs in their territory on two of the tributaries, Wakal and Sei, of Sabarmati for irrigation in Sirohi district and for generation of power. The storage for power from these dams, if constructed, would be available for irrigation in Gujarat.

Rupen and Saraswati

8·6 Beyond the Sabarmati, the Navagam canal will cross the Rupen and then the Saraswati river both originating in Gujarat. Rupen is a small river which cannot be of use because there are no storage sites on it. It is believed that with the construction of a barrage on the Saraswati and a possible storage above, about half of its probable runoff can be used for irrigation of local areas. The balance cannot be used.

Banas

8·7 The last important river to be crossed by the Navagam canal is the Banas which has a catchment of 2,800 sq. miles, of which 1,420 sq. miles lie in Rajasthan. The Dantiwada dam on this river in Gujarat which is nearing completion will intercept 1,105 sq. miles and will be used for irrigation of high areas which cannot be served by any existing or proposed works.

8·8 A reservoir is also proposed by Gujarat on the Sipu, a tributary of the Banas, in its own territory to intercept a catchment of 487 sq. miles for areas in its own command.

8·9 The flow from the catchment of about 1,200 sq. miles below Dantiwada and Sipu projects, which is all in the plains, cannot be used in any appreciable measure as there are no dam sites for storage. If any diversion weirs are found possible, some of the water can be used for irrigation in an area of 1·7 lakh acres on the right bank which has no other sources of supply.

Mahi River

8·10 The Mahi river rises from the northern slopes of the Vindhya ranges in Madhya Pradesh and after running for 360 miles through Madhya Pradesh, Rajasthan and Gujarat, falls into the Gulf of Cambay. The catchment area in the various States is as under :—

Madhya Pradesh	..	1,789 sq. miles
Rajasthan	..	6,211 sq. miles
Gujarat	..	5,000 sq. miles

8·11 The catchment is to a considerable extent hilly and covered with forests and has an average annual rainfall of 32", most of which falls during the monsoon months of July, August and September and almost 94 per cent of the runoff occurs in these months. The total runoff in the nine dry months is only about 6 per cent of the monsoon flow.

8·12 No large irrigation or power projects existed on this river prior to independence and only a few small storage schemes were in operation on some of its tributaries.

8·13 In the Second Five Year Plan, the former Bombay Government prepared a project for a dam at Kadana near Bombay-Rajasthan border. The full reservoir level was proposed to be RL+465 and the storage was to be used for power generation and for irrigation of a commanded area of about 7·7 lakh acres situated on

the right bank lower down. This was to be served by a canal system taking off from Wanakbori weir which was under construction. A high level canal taking off from Kadana to irrigate about 60,000 acres on the left bank was also proposed.

8·14 This dam was strongly opposed by the Rajasthan Government as it would have submerged considerable part of their territory including the famous shrine at Galiakot. After considerable discussion between the States and the Centre, it was decided to reduce the full reservoir level at Kadana from RL+465 to RL+419 and to provide the storage so lost by increasing the capacity of the dam near Banswara in Rajasthan for which a project had meanwhile been proposed in the Rajasthan State.

8·15 In addition to Banswara and Kadana dams mentioned above, projects for which are likely to be approved by the Planning Commission in the near future, sites for dams exist at Baneshwar on the Mahi between Banswara and Kadana and on the Anas, a tributary, at a place a few miles above junction with the Mahi. Only some preliminary work has so far been done on these two sites and detailed investigations have still to be carried out for preparation of project reports.

It is necessary that this work should be expedited as much as possible.

8·16 A comparison of the weighted monsoon rainfall for the catchments up to Banswara and Kadana dam sites reveals that there is no large variation between the two. The rainfall in the upper catchment is only slightly higher than the rainfall in the whole catchment up to Kadana. There is, however, no discharge data for the Mahi except at Pali, located downstream of the Kadana dam site for which it is available for the period 1905—27. In the absence of other observed discharge data, the annual average yield at the various dam sites indicated in Table 8·2 has been worked out on the basis of the proportionate catchments.

TABLE 8·2

Average Runoff at various Dam sites on Mahi system

Sl. No.	Name of Project	Catchment area (sq. miles)	Average annual runoff MAF	Remarks
1.	Banswara ..	2,374	1·57	Average of 1900—1958
2.	Baneshwar ..	6,200	4·00	
3.	Anas ..	1,800	1·17	
4.	Kadana	9,840	6·42	Average of 1891—1958

8·17 The Banswara dam is proposed to be constructed with FRL+928 providing gross storage of 1·65 MAF and live storage of 1·43 MAF. The project provides for an upstream utilisation of 0·23 MAF to irrigate areas in

Madhya Pradesh and an annual utilisation by Rajasthan and Gujarat (for areas under Kadana project whose FRL has been restricted to RL+419 to avoid submergence in Rajasthan) as under :—

Rajasthan	..	0·17 MAF
Gujarat	..	0·63 MAF
Evaporation losses	..	0·13 MAF
Total	..	0·93 MAF

8·18 It is seen that the Banswara dam provides sufficient carryover capacity and will thus utilise all the available flows at this site. The runoff available at Baneswar from its free catchment would, therefore, be about 2·5 MAF, in addition to the above releases.

8·19 Investigations for Baneshwar and Anas schemes are still to be carried out, but it is presumed that the reservoirs at these two sites would provide sufficient storage capacities and carryover to utilise the flow of 2·5 MAF at Baneshwar and 1·17 MAF at the Anas.

8·20 Rajasthan Government hope that it would be possible to develop 60 MW (continuous — 100 per cent LF.) of power at these two sites. This being a non-consumptive use, water to the extent of 3·2 MAF, after allowing 0·47 MAF towards evaporation losses in the two reservoirs, would be available for use at Kadana and in the free catchment up to Kadana. The total irrigation, industrial and Municipal requirements of water on the upstream of Kadana in Rajasthan have been assessed by them at 1·5 MAF.

8·21 The net quantity of water available at Kadana will be as under :—

1. From Banswara	..	0·63 MAF
2. From Baneshwar and Anas (3·2 less 1·5)	..	1·70 MAF
3. From free catchment from Baneshwar up to Kadana excluding catchment of Anas Dam.		1·25 MAF
Total	..	3·58 MAF

8·22 The question of development of the resources of the Narmada river for power and irrigation has been engaging the attention of the various Governments concerned for some years and projects for dams and canal systems have been prepared for some sites by the Central Water & Power Commission on behalf of Madhya Pradesh and former Bombay State. In September 1964, the Central Government appointed the present Committee to draw up a plan for the integrated development of the Narmada water resources for power, irrigation, etc. In Chapter XII, para.12·13, the Committee have expressed the view that the canal taking off from the Navagam reservoir in Gujarat should have a full supply level at head of RL+300. This canal will command almost the whole area which was to be served by the Wanakbori system with Mahi waters drawn from the Kadana and Banswara storage dams. The Committee have suggested that this area should be transferred to the Narmada system, where water and command

are available, and the Mahi water so released be transferred to Rajasthan for areas which are too high to be irrigated from the Narmada system. According to the information furnished by the Rajasthan Government, the canal intended for their area should have a full supply level of about RL+380 at Kadana to adequately serve their land.

8·23 The Kadana dam with its restricted FRL+419 would have a gross storage of 1·26 MAF but the amount available above RL+380, at which the canal for Rajasthan would take off, would be only about 0·89 MAF. Deducting evaporation losses, the net amount would be about 0·75 MAF.

8·24 Until Anas and Banswara dams are built, the water which can be utilised for irrigation from canals taking off at Kadana by Rajasthan would be as under:—

From Kadana Dam	..	0·75 MAF
From Banswara Dam	..	0·63 MAF
From run of the river during July to October.	..	0·70 MAF
Total	..	2·08 MAF

8·25 As the area which is likely to be irrigated in Rajasthan is about 7·5 lakh acres (in addition to 1·0 lakh acres to be irrigated at the tail of FSL+300 Navagam canal), the quantity of water required with delta of 2·5 feet at canal head would be about 1·88 MAF. Of this, about 0·70 MAF would be available from the run of the river in the months from July to October and the balance of 1·18 MAF will have to be drawn from storage. It has been mentioned above that the storage at Banswara and Kadana after deducting losses is 1·38 MAF. As Rajasthan then will take 1·18 MAF, this would leave 0·20 MAF for Gujarat.

8·26 It may, however, be mentioned that the canal from Kadana to Rajasthan will pass for about 200 miles through Gujarat territory and it would not be fair during the period of a decade or more until the Anas and Baneshwar dams are constructed, to entirely deprive the farmers on the way of the water carried by the canal.

It is, therefore, proposed that of the storage at Kadana and Banswara, $\frac{2}{3}$rds should be used by Rajasthan and $\frac{1}{3}$rd by Gujarat. Gujarat will, in addition, be entitled to as much water as they need during July, August, September and October when the river discharge is adequate for all demands.

8·27 When Anas and Baneshwar dams are constructed for power generation in Rajasthan, a further quantity of 1·70 MAF of storage will be available which should also be shared between Gujarat and Rajasthan in the same proportion of 1:2 until the requirements of Rajasthan for its area of 7·5 lakh acres of irrigation are fully met. The excess thereafter may be entirely at the disposal of the Gujarat Government.

8·28 The above calculations take into consideration, a quantity of 1·5 MAF which Rajasthan expect to utilise in their own territory by completing minor and medium irrigation works on the tributaries of the Mahi. As the utilisation

of such a large quantity of water in a limited area, largely hilly, would take a long time, it is believed that the utilisation from the run of the river at Kadana during July to October could not be materially affected by construction of Anas and Baneshwar

8·29 In the project report for Kadana dam, Gujarat State have shown that firm continuous power of 6,000 KW would be generated at the Kadana dam during transmission of water from the dam to the Wanakbori weir which is situated at a lower level. With the high level canal at FSL+380 this power generation would no longer be possible. Power, however, will be generated by Rajasthan from Baneshswar dam and from the Anas and Baneshwar dams. It is understood that the total generation at all these places would be about 90,000 KW continuous.

As Rajasthan and Gujarat would, according to the Committee's recommendation, participate in an integrated system of dams and canals, it is suggested that the total power generated should be shared between the two partners in the ratio in which water is shared, viz., Rajasthan 2 : Gujarat 1.

Sharing of cost

8·30 The cost of the dams and works charageable to power and irrigation, respectively, and the benefits therefrom should be shared between the two States in the ratio of 2 for Rajasthan and one for Gujarat subject to such marginal adjustments as may be mutually agreed upon.

Free catchment of the Mahi below Kadana

8·31 The Mahi has a free catchment of about 2,000 sq. miles between Kadana and Wanakbori which is expected to yield about 1·00 MAF. Of this, about half is proposed to be used by Gujarat for irrigation and industrial use by building a reservoir on the Panam, a tributary of the Mahi, which would intercept a catchment of about 900 sq. miles.The remaining yield of about 0·5 MAF together with any overflow of Kadana would probably flow down the river to Wanakbori in short spates, but it may be possible to use some of the water in the Wanakbori canal system and to that extent reduce the draw from the reservoir at Navagam. As the quantity is likely to be small, no adjustment on this account in the calculations for requirements at Navagam have been made.

CHAPTER IX

NAVIGATION

9·1 With regard to navigation on the Narmada river, the *ad hoc* Committee set up by the Government of India in the Ministry of Works, Mines and Power in 1948 *inter alia* observed as follows (Chapter IV, para. 4·3) :—

> "It appears feasible to.....extend navigation from the river's outfall in the sea right up to and beyond Hoshangabad, i.e., almost to the heart of the country."

9·2 The Inland Water Transport Committee appointed by the Government of India, under the Chairmanship of Shri B. K. Gokhale (I. C. S. Retd.), in their report in 1959 had stated that various multipurpose projects were likely to come up on the Narmada in future years which would improve its navigability in its higher reaches. This Committee were of the opinion that navigation aspect should be given adequate consideration while planning such multipurpose projects.

9·3 The Central Water & Power Commission have studied in detail the aspects of developing inland navigation and they consider that the unified multipurpose development of river systems could make vast stretches navigable and by interconnecting some of these rivers, a net-work of waterways from coast to coast could be created. According to a rough outline plan prepared by them, the following schemes linking the Narmada were envisaged :—

(*i*) with the Sone (tributary of the Ganga) *via* the Johilla, a tributary of the Sone ;

(*ii*) with the Sone *via* the Hiran (tributary of Narmada) and Katni Nadi (tributary of Sone) ;

(*iii*) with the Yamuna *via* the Bearma and the Ken and Hiran ;

(*iv*) with the Godavari *via* Wainganga (tributary of Godavari).

If at a later stage, navigation facilities on the Narmada could be carried to its sources on the Amarkantak Plateau, a navigation link could be established with the Mahanadi system.

9·4 Detailed navigation surveys carried out by the Central Water & Power Commission have revealed that it would not be possible to develop navigation on the Narmada, upstream of Navagam, in its present state by river training or any such means, because of rock out-crops and steep slope with large number of rapids.

Such navigation should, however, become possible with the construction of suitably located reservoirs and, where necessary, intermediate lift weirs which would make the Narmada river navigable to the uppermost reservoir of the system and even beyond.

9·5 Navigation is practised at present to a considerable extent between the mouth of the Narmada and the city of Broach and fairly large size barges are used for transport of goods. It is possible without very much expense to carry on navigation in the sandy reach above Broach, which extends to about 20 miles

below Navagam dam site if traffic warrants. Beyond this place, it is not possible to take boats on account of rocky out-crops and rapids except with the construction of suitable works.

Committee's Proposals (Plates IX-1, IX-2 and IX-3)

9·6 After full development of the Narmada valley and the construction of a series of reservoirs and small lift dams, where required, there will always be adequate depths to enable boats to go from the sea, both at the Gulf of Cambay and at Kandla port, right into the heart of Madhya Pradesh, if adequate lockage facilities for negotiating the regulators, weirs and dams on the way are provided.

From Broach To Navagam Reservoir

9·7 For the portion below Navagam, it would be necessary to construct a barrage with a navigation lock at a place between 12 to 25 miles below Navagam Dam and provide link for navigation to the main Navagam canal through the Sinor branch of that canal. Boats coming from the sea can then go through the locks above the barrage, from there into the Sinor branch and then through another set of locks into the main canal, the proposed offtake of which is at RL+300 at its head. (Chapter XII, para. 12·12). From this level they can be lifted into the Navagam reservoir by a series of navigation locks or other suitable ship lifts (*vide* Plate IX-2). The only major change that will be required in the head reach of the Navagam canal would be to increase the size of the tunnel connecting ponds No. 2 and 3 to provide headroom for boats and space for towpaths. Details of this are indicated in Plate IX-1.

Lockage arrangements for negotiating the other dams at Barwaha, Punasa and dams higher up can be made as necessary.

Lift weirs for navigation locks will have to be constructed in the Navagam, Punasa and other reservoirs whose levels fluctuate. Similarly, lift weirs will be required to negotiate the length between the Chinki reservoir and the Bargi dam and reservoir. If navigation has to be carried upstream, more lift weirs may have to be constructed.

9·8 It will be desirable to provide for navigation structures at the dams and regulators and make the bridges on the navigable canal or canals fit for navigation, as integral part of the works. Once the canal system has been completed, it can be made navigable at small additional cost. Therefore, it will be poor economy not to use the canal system for navigation right from the beginning.

In case of reservoirs, the levels of which fluctuate due to withdrawals for irrigation and/or power, lift weirs will have to be constructed to negotiate such fluctuations in levels and suitable lock structures provided with these lift weirs.

Kandla Port to Navagam Reservoir

9·9 It will be seen from the layout of the canals (*vide* Plate IX-1) in Gujarat that the Banni branch would run close to Kandla port. It is recommended that this branch be connected by navigation locks, artificial channels and natural creeks with the Kandla port, by navigation lock with the main Navagam canal, thus connecting Kandla port to Navagam reservoir and above for inland water

CHAPTER X

FLOOD CONTROL

10·1 The Narmada in Madhya Pradesh flows in a deep channel with high banks which are rarely overtopped even in exceptional floods. Floods, therefore, do not present any serious problem in Madhya Pradesh and no special measures on this account are required.

10·2 Below the Hiranphal-Navagam gorge, the Narmada spreads out into the flat Gujarat plains and flows in a wide stream with low banks in the rest of its course up to the Gulf of Cambay. Serious floods with a frequency of once in five to six years occur in this part and damage is caused to life and property. During the last 50 years, such floods have occurred in 1921, 1926, 1927, 1928, 1934, 1935, 1942, 1944, 1950, 1954 and 1961. The flood of July, 1927 is reported to have been the highest in recorded history.

10·3 Besides damaging crops and flooding villages above and below Broach, the city of Broach itself is affected with inundation several feet deep. Most of the trouble is on the left bank of the river and the loss can be much aggravated if a high flood synchronises with a high tide from the sea. The Government have to spend considerable amounts in giving gratuitous relief to those affected by floods. Development of agriculture in the flood area is also affected owing to insecurity.

10·4 In preparing the Navagam project (FRL 425—Gross storage 5·3 MAF), the Gujarat Government anticipated that the dam would, besides giving irrigation and power benefits, moderate the peak flood from 22 lakh cusecs to 17 lakh cusecs and afford substantial relief from flood damage to the low lying areas of Broach district.

Committee's Proposals

10·5 The proposals of the Committee envisage increasing the Navagam storage (FRL+500) to 14·4 MAF (11 MAF live) and providing live storage of another 17 MAF in the reservoirs upstream of Navagam or a total live storage of 28 MAF. The greater, however, the storage capacity of the terminal reservoir, the more effective will be the flood control.

The exact effect of all these storages on the flood situation below Navagam can be known only after a detailed study of flood routing, but it is evident that with proper and co-ordinated flood regulation at the various dams, the flood peak at Navagam would in all probability be reduced to relatively harmless proportions, so that floods would cease to be a material problem.

No special measures have, therefore, been suggested in the Report for flood moderation.

CHAPTER XI

COMMITTEE'S APPROACH TO THE PLAN OF NARMADA DEVELOPMENT

11·1 In their meeting from 14th to 18th December, 1964, at which the State representatives were also present, the Committee laid down the following basic guide-lines in drawing up the Master Plan for the optimum and integrated development of the Narmada water resources:—

(1) National interest should have over-riding priority.

The Plan should, therefore, provide for maximum benefits in respect of irrigation, power generation, flood control, navigation, etc. irrespective of State boundaries;

(2) Rights and interests of States concerned should be fully safeguarded subjects to (1) above;

(3) Requirements of irrigation should have priority over those of power;

subject to the provision that suitable apportionment of water between irrigation and power may have to be considered, should it be found that, with full development of irrigation, power production is unduly affected;

(4) Irrigation should be extended to the maximum area within physical limits of command, irrespective of State boundaries, subject to availability of water; and,

in particular, to the arid areas along the International border with Pakistan both in Gujarat and Rajasthan to encourage sturdy peasants to settle in these border areas (later events have confirmed the imperative need for this) ; and

(5) All available water should be utilised to the maximum extent possible for irrigation and power generation and, when no irrigation is possible, for power generation.

The quantity going waste to the sea without doing irrigation or generatin gpower should be kept to the unavoidable minimum.

Power

11·2 Electric power can be generated at Hydro-Electric Stations or at Thermal Stations burning coal, oil or natural gas or by using atomic energy.

Madhya Pradesh have large resources of coal and some important coal based power stations, recently constructed or under construction. Oil and natural gas

have been found in Gujarat in recent years and these will be put to use as available. Maharashtra also have coal but it is limited in quantity and extent. An atomic power station at Tarapore to benefit Gujarat and Maharashtra is under construction, while some more are being planned in other parts of the country.

11·3 The power generation in the Narmada basin should, therefore, be planned for integrated use with these alternative sources. The various kinds of power stations usually feed into a common grid so that shortfall from any source may be met from other sources by providing additional installations, if necessary. This grid arrangement will incidentally maximise power output from the installations in the grid.

Agriculture

11·4 Agriculture constitutes the base for all development—economic, industrial or defence. Agricultural production has, therefore, been given the highest priority. Agricultural output must be raised not only to meet the steady increase in population but also to provide surpluses for other sectors of economy.

11·5 Since 1950 we have imported 7·3 million tonnes of rice and about 39 million tonnes of wheat, or a total of 46·3 million tonnes. During 1964 alone, we imported 0·644 million tonnes of rice and 5·621 million tonnes of wheat. This indicates the magnitude of drain on our economy and foreign exchange resources.

It is in this background that the Committee have felt it necessary to give priority to irrigation over power, for without irrigation, be it natural rainfall, open wells, tube-wells or minor, medium or major irrigation works, there can be no assured agriculture. Agriculture depending only on rainfall even in regions where rainfall is plentiful, has proved to be a gamble. With late rainfall, sowings are affected; with the failure of rainfall at the time of maturing, crops are damaged and even destroyed. In drought years, the agricultural output is severely limited. For stable production it is, therefore, necessary to have assured irrigation which will make agriculture independent of the vagaries of rainfall as also of arid conditions.

11·6 For maximising agricultural output, it is necessary to adopt improved agricultural practices, better seeds, optimum use of fertilisers, pesticides, etc. But again, no improved agricultural practices or the use of fertilisers will be of much avail unless there is adequate water available for the crops.

The Committee, therefore, feel that the first priority for the use of Narmada water should go to irrigation and the second to power generation.

Fortunately, it is possible to satisfy the full needs of irrigation without sacrificing power generation for at least the next 25 years or so on

the basis of the Committee's calculations with Navagam FRL+500, *vide* Table 11·1.

TABLE 11·1

Phasing of Narmada development (Period 30 years)

	4th Plan 1965--70	5th Plan 1970—75	6th Plan 1975--80	7th Plan 1980—85	8th Plan 1985—90	9th Plan 1990—95
Irrigation (Lakh acres)						
Madhya Pradesh and Maharashtra ..		10·1	20·1	35·1	50·1	65·1
Gujarat and Rajasthan		10 4	26	41	46·8	46·8
Total		20·5	46·1	76·1	96·9	111·9
Power (MW at 60 % L.F.)						
Funasa and other schemes in Madhya Pradesh. ..		554	1,198	1,063	843	793
Navagam (FRL+500)						
(*a*) River bed		*1,000	+1,000	725	430	245
(*b*) Canal		54	140	226	266	266
Total Navagam		1,054	1,140	951	696	511
Grand Total		1,608	2,338	2,014	1,539	1,304

* At 84 % L.F. +At 68 % L.F.

Should at the end of 25 years or so the supplies available for power drop down substantially, it should be possible to make good bulk of the loss by raising the dead storage level at the tail reservoir at Navagam coupled with integrated operation with other sources of power; and also by augmenting irrigation supplies by pumping from sub-soil reservoirs both in Madhya Pradesh and Gujarat, thereby releasing appreciable quantities of water from surface reservoirs for power generation.

National and State interests served

11·7 From a study of the development of irrigation and power during the successive Five Year Plans, the results of which are given in Table 11·1 above and Plates XI-1, XI-2 and XI-3, it appears that—

(*a*) the rights and interests of both Madhya Pradesh and Gujarat will be adequately safeguarded, both in respect of water and power, and

(*b*) water will be made available for irrigation of border areas of Gujarat and Rajasthan with Pakistan thereby ensuring security of the country and serving best the national interests through greater food production.

Intergration of Mahi system with the Narmada

11·8 The Rajasthan international border areas are proposed to be provided with flow irrigation from the Navagam canal for one lakh acres of irrigation only. One proposal was to provide irrigation to additional 7·5 lakh acres of Rajasthan from this canal by lift. This was, however, found to be both expensive and wasteful. A satisfactory alternative was found in feeding these 7·5 lakh acres from Mahi river by gravity flow utilising the 1·9 MAF of its water, originally

earmarked for irrigation of 6·57 lakh acres of Gujarat area close to and under command of the Navagam canal and providing irrigation water to these 6·57 lakh acres from the Navagam canal.

It is further proposed to undertake the optimum development of the Mahi and Sabarmati rivers for irrigation and power development in intergration with the Narmada development. As indicated in Chapter VIII, this will require the construction of three additional dams upstream of the Kadana dam, two on the Mahi main and one on its tributary Anas, to give a total live storage of about 3·83 MAF in addition to 0·89 MAF at the Kadana dam or a total of about 4·72 MAF. Similarly, it may be possible to construct two dams on the tributaries of the Sabarmati in Rajasthan to utilise their waters for irrigation and power. Table 11·2 gives the tentative storage and power picture on these dams.

TABLE 11·2

Particulars of storage on Mahi System

Serial No.	Name of Project	River	Catchment area at dam site (sq. miles)	Average annual runoff (MAF).	Proposed FRL	Gross storage (MAF)	Live storage (MAF)	Power production in MW @ 60 % L.F.	Remarks
1	Banswara ..	Mahi	2,374	1·57	+928	1·65	1·43	50	0·63 MAF to be let down for use ex-Kadana dam.
2	Baneshwar	Mahi	6,200	4·00	NA	2·00	1·62	100	These projects are still to be investigated. Storage figures are tentative.
3	Anas	Anas	1,800	1·17	NA	0·96	0·78		
4	Kadana	Mahi	9,840	6·12	+419	1·26	0·89	..	Mahi water to be diverted by a canal (off-take level +380) to irrigate areas in Gujarat and Rajasthan.
	Total ..		..	..	..	5·87	4·72	150	MW

Water wasted to the sea

11·9 With regard to waste of water to the sea, the Committee are of the view that with adequate storage capacity and storage dams located at the most strategic positions on the Narmada and built to optimum heights, it would be possible, through maximum utilisation for irrigation and regulated utilisation for power,

to cut to the barest minimum the quantity of water going to the sea. The water used for irrigation will be consumptive use and will not go down to the sea. But water passing through turbines at the lowermost power dam of the system which cannot be used for irrigation will be used for generation of power and thereafter go to the sea.

The figures of water going to the sea during the different Plans after use for irrigation and power, assuming the terminal reservoir at Navagam with FRL+500, are given in Table 11·3.

TABLE 11·3

Water going to the sea after use for Irrigation and Power

		MAF
4th Plan (1965—70)	..	36·00
5th Plan (1970—75)	..	29·40
6th Plan (1975—80)	..	24·00
7th Plan (1980—85)	..	17·55
8th Plan (1985—90)	..	12·80
9th Plan (1990—95)	..	9·50

In this connection reference may be made to Chapter XIV, Table 14·3.

CHAPTER XII

Terminal storage Dam, optimum height and power studies

12·1 The developments proposed by Madhya Pradesh at and above Punasa and at Barwaha concern that State only and no difference of opinion has been expressed by other States about the sites of dams proposed. Below Barwaha, however, divergent views are held by the three States concerned, the contending sites being Hiranphal, Jalsindhi and Navagam.

Madhya Pradesh Proposals

12·2 In the Master Plan submitted to the Committee by Madhya Pradesh for developments below Punasa, it has been proposed that a dam with FRL+465 and MWL+470 (Document No. MP/11, Vol. II, page 19, Statement XI) should be constructed at Hiranphal near the head of Hiranphal—Navagam gorge. They have also proposed another dam at Jalsindhi with FRL+355 and tail level+210. They thus propose to use almost the entire drop available to them for the generation of power, leaving the head between RL+210 and RL+80 for the Gujarat State to utilise for power generation.

12·3 Regarding Hiranphal (river bed level+320), the 1964 Project Report on Narmadasagar (Punasa) (Document No. MP/1) by the Madhya Pradesh Electricity Board (page 8), has proposed the construction of a dam at this site to FRL+490 which will also provide for storage of the runoff from catchment below Punasa.

In his report (Document No. MP/12) on the reconnaissance aerial survey of the river Narmada, dated the 9th October, 1964, the Chairman, Madhya Pradesh Electricity Board, has stated:

"3. *Hiranphal Reservoir*

* * * *

(*iv*) The raising of Hiranphal FRL to 500 will no doubt submerge some good cultivated lands besides the largely eroded areas. But this sacrifice would be worthwhile. At higher levels, the lands appear to be very much richer so that they can be irrigated by lift. Therefore, the higher the level of the Hiranphal lake, the greater will be the irrigation benefits to these rich lands, because the pumping head will be correspondingly reduced. I would, therefore, strongly advocate Hiranphal FRL 490—500.

"4. *Jalsindhi Scheme*

* * * *

If the storage of Narmada waters is to be increased, the level of Hiranphal may be raised because the lands and villages above Hiranphal appear less promising".

Maharashtra Proposals

12·4 In their memorandum (Document No. M/1) submitted to the Committee, the Maharashtra Government proposed a high dam at Jalsindhi at FRL varying from +460 to +500 with tail level at +210 as in the plan of Madhya Pradesh.

12·5 Subsequently, the Madhya Pradesh plan seems to have been accepted by Maharashtra and in an agreement entered into between the two Governments, it has been proposed that the dam at Jalsindhi, which is located on the common boundary, should be built for FRL+355 jointly by Madhya Pradesh and Maharashtra. The cost and benefits are to be shared according to a formula based on the fall in the river bed in each State. A copy of the agreement is at Annexure XII-1. The quantums of power available to each State under this agreement for various stages of water utilisation are given in Table 12·1.

TABLE 12·1

Share of power from Jalsindhi as per agreement

Jalsindhi FRL+355 TWL+210 — Hiranphal FRL+465 TWL+355

Year		Total power generated MW at 60 per cent L F	*Share of Madhya Pradesh	Maharashtra
1975	..	425	322	103
1980	..	418	317	101
1985	..	342	259	83
1990	..	256	194	62
1995	..	206	156	50

*As per the agreement, power is to be shared by Madhya Pradesh and Maharashtra in the ratio of

$$A+\frac{B}{2} : \frac{B}{2}$$

Where A=fall of river in Madhya Pradesh alone

B—fall of the river on the common boundary which starts at RL+280

A=355—280=75

B=280—210=70

Share of Madhya Pradesh (75+35=) 110 : Share of Maharashtra 35

The above calculations are with tail water level at Jalsindhi of +210. With the tail water level raised for feeding the Navagam canal with FSL+300, there will be little power generation at Jalsindhi.

In this connection please refer Tables 13·1 and 13·2 (Chapter XIII).

Gujarat Proposals

12·6 The sanctioned Broach Irrigation Project Stage I, as approved by the Planning Commission (August 1960), provides for the construction of a dam with FRL+162 with wider foundations for greater height in Stage II which contemplated raising the dam to FRL+320.

However, during subsequent examination of this project, the Gujarat Government came up with the proposal for the construction of the Navagam dam to a height of FRL+425 so as to derive greater benefits for irrigation and power.

In their technical memorandum (Document No. G/16) submitted to the Committee in January 1965, the Gujarat Government have proposed a still higher Navagam dam with FRL+490 and explained in detail the reasons which have led to the framing of their present Navagam dam proposal.

Committee's Studies

Power, Storage and Submergence

12·7 In view of these conflicting proposals for harnessing the river below Barwaha, the Committee had to examine these in detail and make independent studies. Mass curve studies were carried out to examine the benefit that would accrue from equivalent FRLs of various dams or combination of dams with a total irrigation withdrawal of 23·80 MAF (which does not include reservoir losses) for the following alternatives:—

(1) Hiranphal (TWL+320) FRL varying from +460 to +500 ; Jalsindhi FRL+320 (TWL+210) ; Navagam FRL+210 ;

(2) Hiranphal FRL varying from +460 to +500 ; Jalsindhi omitted ; Navagam with FRL+320 ;

(3) Hiranphal omitted ; Jalsindhi FRL varying from +460 to +500 ; Navagam with FRL+210 and also with FRL+320 ; and

(4) Hiranphal omitted ; Jalsindhi omitted ; Navagam (TWL+80) FRL varying from +460 to +500 and (*a*) Canal taking off at +210 and (*b*) at +300 levels.

These studies are indicated in detail in Annexure XII-2. The results of these are given in Table 12·2 for irrigation withdrawals of 15·75 MAF, assumed 20 years from start and Table 12·3 for 23·80 MAF at full development of irrigation, assumed 30 years from start, both figures being net, i.e., exclusive of reservoir losses.

TABLE 12·2

Power generation at 60 per cent LF with irrigation withdrawals 15·75 MAF net at the end of 20 years from start

FRL	+500	+490	+480	+465
	Power in MW			
A. Navagam Canal Offtake Level +210				
I. Hiranphal TWL+320 ..	428	394	364	330
Jalsindhi FRL +320 TWL +210 ..	288	275	266	258
Navagam FRL +210 TWL +80	169	154	143	134
Total ..	885	823	773	722
Less power for lift irrigation of 29 lakh acres in Gujarat and Rajasthan (Annexure XII-3)	(-)160	(-)160	(-)160	(-)160
Net ..	**725**	**663**	**613**	**562**
II. Jalsindhi TWL + 210 ..	757	707	658	595
Navagam FRL +210 TWL +80 ..	228	212	196	176
Total ..	985	919	854	771
Less power for lift irrigation of 29 lakh acres in Gujarat and Rajasthan (Annexure XII-3).	(-)160	(-)160	(-)160	(-)160
Net ..	**825**	**759**	**694**	**611**
III. Navagam TWL+80	1075	1007	959	900
Less power for lift irrigation of 29 lakh acres in Gujarat and Rajasthan (Annexure XII-3).	(-)160	(-)160	(-)160	(-)160
Net ..	**915**	**847**	**799**	**740**
B. Navagam Canal Offtake Level +300				
I. Hiranphal TWL+320 ..	428	394	364	330
Navagam FRL + 320 TWL +80 ..	314	287	266	248
Total ..	**742**	**681**	**630**	**578**
II. Jalsindhi TWL+320 ..	420	382	347	302
Navagam FRL +320 TWL +80 ..	422	392	363	326
Total ..	**842**	**774**	**710**	**628**
III. Navagam TWL+80 ..	**951**	**885**	**836**	**776**

TABLE 12·3

Power generation at 60 per cent L F with irrigation withdrawals 23·80 MAF net at full Development of 30 years from start

FRL	+500	+490	+480	+465
	Power in MW			
A. Navagam Canal Offtake Level +210				
I. Hiranphal TWL+320 ..	275	247	224	199
Jalsindhi FRL+320 TWL+210 ..	185	172	163	155
Navagam FRL+210 TWL+80 ..	16	..	..	..
Total ..	476	419	387	354
Less power for lift irrigation of 29/32/35/ lakh acres in Gujarat and Rajasthan (Annexure XII-3). ..	(—)160 (29 lakh acres)	(—)180 (32 lakh acres)	(—)200 (35 lakh acres)	(—)200 (35 lakh acres)
Net ..	**316**	**239**	**187**	**154**
II. Jalsindhi TWL+210 ..	507	474	436	386
Navagam FRL+210 TWL+80 ..	65	54	41	22
Total ..	572	528	477	408
Less power for lift irrigation of 35 lakh acres in Gujarat and Rajasthan (Annexure XII-3). ..	(—)200	(—)200	(—)200	(—)200
Net ..	**372**	**328**	**277**	**208**
III. Navagam TWL+80 ..	658	602	563	515
Less power for lift irrigation of 35 lakh acres in Gujarat and Rajasthan (Annexure XII-3). ..	(—)200	(—)200	(—)200	(—)200
Net ..	**458**	**402**	**363**	**315**
B. Navagam Canal Offtake Level +300				
I. Hiranphal TWL+320 ..	275	247	224	199
Navagam FRL+320 TWL+80 ..	29	..	..	..
Total ..	**304**	**247**	**224**	**199**
II. Jalsindhi TWL+320 ..	281	255	230	195
Navagam FRL+320 TWL+80 ..	120	100	76	41
Total ..	**401**	**355**	**306**	**236**
III. Navagam TWL+80 ..	**511**	**456**	**419**	**369**

The above tables conclusively indicate that, for the same offtake level of Navagam Canal, a high dam at Navagam gives optimum results for power benefits as compared to dams of corresponding FRL at Jalsindhi and Hiranphal.

12·8 Another important factor that goes in favour of high Navagam Dam is the enormous additional storage afforded by it for corresponding levels. Table 12·4 gives the gross and live storage capacities at the three dam sites for equal reservoir levels.

TABLE 12·4

Storage capacities of Dams in lower reach

(Storage in MAF)

	HIRANPHAL			JALSINDHI			NAVAGAM		
FRL	Gross	Dead	Live	Gross	Dead	Live	Gross	Dead	Live
+ 500	5·55	1·25	4·30	8·23	0·65	7·58	14·40	3·18	11·22
+ 490	4·16	1·25	2·91	6·72	0·65	6·07	12·10	3·18	8·92
+ 480	3·07	1·25	1·82	5·22	0·65	4·57	10·67	3·18	7·49
+ 465	1·95	1·25	0·70	3·65	0·65	3·00	8·70	3·18	5·52

It will be seen that for a FRL of +500, a dam at Navagam provides 8·85 MAF more gross storage than a dam at Hiranphal and 6·17 MAF more gross storage than one at Jalsindhi. With dead storages of 3·18 MAF. at Navagam and only 1·25 MAF at Hiranphal and 0·65 MAF. at Jalsindhi, the live storage available at Navagam will be 6·92 MAF more than that at Hiranphal and 3·64 MAF more than that at Jalasindhi.

This additional storage will permit greater carryover capacity, increase power production and assure optimum irrigation and flood control.

12·9 It should be clearly understood that whatever the height of the dam at Hiranphal, a dam at Jalsindhi or at Navagam of the same FRL would not submerge appreciably any greater acreage of cultivable areas (Table 12·5) because practically all the cultivable areas are above Hiranphal and in the 70 miles length of gorge between Hiranphal and Navagam there is little in the way of cultivable area. Barwani town in Madhya Pradesh, upstream of Hiranphal will not be submerged at FRL +500.

TABLE 12.5

Details of Submergence

(Submerged areas in acres)

FRL	+500		+ 490		+ 480		+ 465	
Dam site	Gross	Culti-vable	Gross	Culti-vable	Gross	Culti-vable	Gross	Culti-vable
Hiranphal ..	156,000	91,400	127,200	71,200	98,500	51,000	60,000	25,000
Jalsindhi ..	181,600	95,000	157,000	74,500	122,000	54,000	83,000	27,000
Navagam ..	218,600	99,200	187,300	78,100	156,000	57,000	15,000	30,000

For comparison, Punasa (FRL+860) will submerge 2,25,000 acres gross of which 1,14,000 acres will be culturable.

Water wasted to sea

12·10 The average quantity of water that will be wasted annually to sea on full development without being used for irrigation or generation of power with different dams constructed to equivalent full reservoir levels, is given in Table 12·6 :

TABLE 12·6

Water wasted to sea without being used for irrigation or generation of power

FRL	+ 500	+ 490	+ 480	+ 465
			MAF	
1. Hiranphal ..	9·15	9·98	10·62	11·31
2. Jalsindhi ..	7·15	7·74	8·35	9·35
3. Navagam ..	5·60	6·22	6·61	7·15

Average annual run off of the river is taken as 36 MAF.

Optimum offtake level for Navagam Canal

12·11 In the view of the Committee, the full supply level of the canal which would take off from Navagam dam needs to be determined before any recommendation is made about the location and height of the dam or dams to be constructed in the Hiranphal-Navagam gorge. This is discussed below:—

(*a*) The *Gujarat* Government in their memorandum have proposed that the FRL of the canal should be at RL+300. It is intended to command an area of 87·6 lakh acres gross and 56·5 lakh acres C. C. A. and to irrigate only an area of 34·7 lakh acres. This excludes an area of 6·57 lakh acres under Mahi command which also can be irrigated by the proposed Navagam Canal and 4·5 lakh acres in the Great Rann of Kutch. To this has to be added 2 lakh acres gross and 1 lakh acre irrigation in Rajasthan, thus bringing the total irrigation to 46·8 lakh acres.

(*b*) *Maharashtra* have, however, in their memorandum, stated that the site of the Navagam dam should be shifted to the place about 3 miles downstream, where it was originally proposed and the Navagam Canal should have FSL

+185/190. According to them, this canal would command 35·9 lakh acres by flow and 19·1 lakh acres by lift in the Saurashtra and Kutch area. But that will still leave a balance of 25·5 lakh acres between the RL+300 and RL +185/190 canals which can be commanded by the RL+300 Navagam canal. This additional area of 25·5 lakh acres, according to Maharashtra, can be irrigated partly by further lift and partly by flow from the Mahi reservoir.

The power requirements for the lift under the Navagam RL+185/190 canal has been assessed at 86 MW at 60 per cent load factor by Maharashtra.

(*c*) According to *Gujarat* calculations, the gross command under FSL +185/190 canal by flow would be 21·1 lakh acres against 35·9 lakh acres indicated by Maharashtra and if an equivalent area is to be served from Narmada, the total gross area under lift would be 66·5 lakh acres. The average power requirement for lifting the irrigation supplies to this area has been worked out as 167 MW firm (100 per cent L. F.). With the fluctuating demand of irrigation, the maximum power requirement for lifting has been estimated at 224 MW. Lifting the water requirement for Rajasthan to RL+300 at the Navagam dam site itself would require power of the order of 86 MW continuous. Thus, according to the Gujarat Government, the total power required to serve the full area, as envisaged, would be 310 MW continuous (against 86 MW at 60 per cent load factor mentioned by Maharashtra) and would have to be met from the power generation at Navagam which, according to Gujarat, will just not be available.

According to the Gujarat Government memorandum, the FSL+300 canal project includes provision for generation of average 53 MW of power at 60 per cent load factor at the fall on the Saurashtra branch to be used for lifting water to serve 6·8 lakh acres of high areas in Kutch and Saurashtra on the same branch. The average requirement of power for the year for lifting will be 68 MW (at 60 per cent load factor) which is only 15 MW more than that generated at the canal fall. This small excess can easily be met from the power system.

Committee's Analysis :

12.12 The Committee have worked out that the power required for lift irrigation based on the area, crop pattern and water requirements recommended by them will be of the order of about 200 MW at 100 per cent L. F. (Annexure XII-3). The power requirement will be greater in the initial stage when a larger quantity of water will be required for land reclamation and leaching operations. The extra power that can be generated at the Navagam dam if canal is taken out at RL+185/190 instead of RL+300 will be about 96 MW at 100 per cent load factor. Thus FSL+185/190 canal will consume at least 104 MW at 100 per cent L. F. more of power than the additional generation.

To this has to be added the cost of pumps, pipe lines, carrier canals and other civil works at various places or, alternatively, a single high level canal with one huge central pumping plant. Both these alternatives are going to be prohibitive in cost.

In the view of the Committee, it will be wasteful to use power for lifting water when flow irrigation can be easily provided from FSL+300 canal.

The Gujarat proposal (FSL+300 canal) provides for 68·5 lakh (gross) acres by flow and 19·1 (gross) lakh acres by lift. The water dropping in Saurashtra branch at mile 8 in the trough will generate 53 MW of power at 60 per cent load factor. The water to be lifted at the end of trough will need 68 MW of power or a net excess of 15 MW for the entire lift which will have to be met from the general Narmada power system as against 200 MW as worked out above.

The Committee have proposed elsewhere to divert the Mahi waters to irrigate areas in Rajasthan and this water will, therefore, not be available for irrigation of areas between RL+185/190 and +300 canal command.

The Committee, taking the national interest into consideration, have proposed to carry irrigation to the areas bordering Pakistan in the Rann of Kutch in Gujarat and Barmer and Jalore districts of Rajasthan. This will be possible only with a+300 FSL Navagam canal with adequate capacity. There is no other possible means of irrigating these vital areas.

12·13 A topographical study indicates that the additional area which can be commanded by taking off the canal at a level higher than RL+300 is very limited because of steep rise in the general ground levels above this contour. The cost of a higher level canal will be much greater for the first nearly 100 miles as it would be running through very undulating country.

It is, therefore, considered that RL+300 is the optimum level for the full supply of Navagam canal at its head.

Optimum full Reservoir level of Navagam Dam

12·14 From detailed calculations given in Annexure XII-4 it has been established that for fully meeting the irrigation needs of Gujarat, the FRL+465 for Navagam dam would be ample. But with the same level of +465 at Hiranphal, there will not be enough storage to meet these irrigation demands in full. A higher dam at Navagam will provide very much more storage and, therefore, additional power besides better flood control. The economics of various heights of the dam have been studied in the light of incremental benefits accruing in additional generation of power against incremental costs. These studies are contained in Annexure XII-4.

Annexure XII-4 establishes that FRL+ 500 for the Navagam dam is the optimum.

Paras 12·7 to 12·10 indicate that the Navagam location is the best for the terminal dam and reservoir for purposes of power generation, additional storage and saving in water wasted to the sea.

Installed capacity at Navagam River bed and canal Power Stations

River bed Power Station

12·15 The amount of power that would be generated at Navagam river bed and canal power stations during various stages of irrigation development with FRL +500 is given in Annexure XII-2, Table XII-2(*c*). With FRL +500 and effective storage of 11·22 MAF, an installed capacity of 1,000 MW should be the correct choice for this power station. This would mean that in the beginning

1,000 MW would be generated at 84 per cent L.F. There would be no difficulty of running this power station at such a high load factor as the load demand is very heavy in this region (*See* Chapter XIV, Para. 14·4). Installation of higher capacity will not be justifiable as on full development of irrigation, power generation would be considerably reduced. No doubt at that stage river bed power station will be running as a peaking station and with an installed capacity of 1000 MW, power would be generated at 15 per cent L.F., which would be the nature of peaking hydro power stations at that time, when major part of power generation will be by thermal stations. Thus the Committee recommend the installation of 1000 MW with one unit of 100 MW as stand-by.

Canal Power station

Installed capacity at this power station would be governed by the maximum amount of power that would be generated by canal discharges on full irrigation development. Maximum power that would be generated would be about 240 MW at 100 per cent L.F. by the canal discharges in the month of October when head will be near maximum. The discharges at the canal are expected to be continuous and the power would be generated at 100 per cent L.F. Thus an installed capacity of 240 MW with one stand-by unit would be the best choice and is thus recommended for installation.

Committee's Conclusions

12·16 Taking all factors into consideration, the Committee are firmly of the view that—

(*i*) the terminal storage dam should be located at Navagam ;

(*ii*) the optimum full reservoir level at this terminal dam works out to RL+500; and

(*iii*) the full supply level of the Navagam Canal at offtake should be RL +300.

(*iv*) the installed capacity at the river bed power station and the canal power station should be 1,000 MW and 240 MW, respectively with one stand-by unit in each power station.

ANNEXURE XII-1

AGREEMENT BETWEEN THE GOVERNMENTS OF MADHYA PRADESH AND MAHARASHTRA ON THE CONSTRUCTION OF JALSINDHI PROJECT

The Governments of Madhya Pradesh and Maharashtra have aggreed to co-operate in the development of hydro-electric power at Jalsindhi on the Narmada river and for this purpose have agreed as follows:—

1. The Government of Maharashtra will carry out the necessary investigations and surveys and prepare a project estimate for the construction of Jalsindhi dam and power house, in accordance with the Master Plan (March 1965) prepared by Madhya Pradesh. This estimate will be considered by the two Governments and, after it has been approved by both the Governments with such modifications as may be necessary, the Government of Maharashtra will undertake the construction of the dam, power house and ancillary works at Jalsindhi in the Fourth Plan.

2. The Government of Madhya Pradesh will give all due assistance in the acquisition of land required in Madhya Pradesh for the Jalsindhi Project and such other facilities as may be necessary for the execution of the project.

3. The costs of the works at Jalsindhi will be shared between Madhya Pradesh and Maharashtra in the ratio of $a+\frac{b}{2} : \frac{b}{2}$ where a is equal to the fall in the river between Hiranphal and the point where one bank of the river enters Maharashtra and b is equal to the fall in the river in the portion where it runs along the boundary between the two States.

4. The net benefits from the Jalsindhi Project (*i. e.* excluding such credits as have to be afforded to the upstream projects for the regulated supplies received at Jalsindhi from those projects and including such credits as would be afforded by downstream projects for the regulated supplies delivered from Jalsindhi) will be shared between the two States in the same proportion as the costs

5. If, at any stage, during investigations, project making or construction of the project, either Governments considers that a change is desirable in the scope or design, etc., of the project, the two Governments would meet and after discussion agree on such changes as may be necessary in the interest of economic development.

6. The two Governments will work out in due course and agree upon agreements for financing the project, for the association of the two Governments in the control of expenditure on the construction, maintenance and operation of the Jalsindhi project and of its operation in the best interests of both the Governments.

7. Apart from the provision of paragraph 5 above, by mutural agreement, the two Governments may, at any stage, make such modifications in the terms of this agreement as may appear to be desirable and necessary.

V. P. NAIK
5/4/65
Chief Minister, Maharashtra State

D. P. MISHRA
Chief Minister, Madhya Pradesh State

Annexure XII 2 (A)

COMPARATIVE STUDY OF POWER GENERATION WITH IRRIGATION WITHDRAWALS 15·75 MAF NET AT THE END OF 20 YEARS FROM START

ALT. I NAVAGAM CANAL OFF TAKE LEVEL +210

	Combination I				Combination II				Combination III			
	Hiranphal +465 Jalsindhi +320 Navagam +210	Hiranphal +480 Jalsindhi +320 Navagam +210	Hiranphal +490 Jalsindhi +320 Navagam +210	Hiranphal +500 Jalsindhi +320 Navagam +210	No Hiranphal Jalsindhi +465 Navagam +210	No Hiranphal Jalsindhi +480 Navagam +210	No Hiranphal Jalsindhi +490 Navagam +210	No Hiranphal Jalsindhi +500 Navagam +210	No Hiranphal No Jalsindhi Navagam +465	No Hiranphal No Jalsindhi Navagam +480	No Hiranphal No Jalasindhi Navagam +490	No Hiranphal No Jalsindhi Navagam +500
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
I· (*i*) Average annual flow at Navagam MAF ..	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94
(*ii*) Live aggregate storage at all storage sites in the entire basin MAF	17·70	18·82	19·91	21·30	20·00	21·57	23·07	24·58	22·52	24·49	25·92	28·22
II. WATER UTILISATION MAF												
(*i*) Gross utilisation for irrigation and power ..	24·27	24·94	25·60	26·43	26·25	27·30	28·03	28·90	28·40	28·96	29·35	29·98
(*ii*) Gross utilisation expressed as percentage of average flow	67·5	69·3	71·2	73·5	73·0	76·0	77·8	80·3	79·0	80·5	81·5	83·3
(*iii*) Net utilization for irrigation (A) in Madhya Pradesh ..	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25
(B) in Maharashtra ..	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10
(C) in Gujarat ..	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15
(D) in Rajasthan ..	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25
Total ..	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75
(*iv*) Evaporation losses ..	2·20	2·42	2·55	2·70	2·20	2·30	2·30	2·40	2·37	2·44	2·53	2·70
(*v*) Total consumptive use (irr. & eva. losses) II (*iii*)+II(*iv*)	17·95	18·17	18·30	18·45	17·95	18·05	18·05	18·15	18·12	18·19	18·28	18·45
III. Balance flowing to the sea (I*i*—II*v*) MAF ..	17·99	17·77	17·64	17·49	17·99	17·89	17·89	17·79	17·82	17·75	17·66	17·49

IV. (*i*) Utilisation for power generation at river bed power-house at Navagam (II *i*—II *v*). MAF	6·32	6·77	7·30	7·98	8·30	9·25	9·98	10·75	10·28	10·77	11·07	11·53
(*ii*) water going to sea unutilised either for irrigation or power generation I*i*—II*i* MAF	11·67	11·00	10·34	9·51	9·69	8·64	7·91	7·04	7·54	6·98	6·59	5·96
Total ..	17·99	17·77	17·64	17·49	17·99	17·89	17·89	17·79	17·82	17·75	17·66	17·49
V. IRRIGATION (in lakh acres)												
Madhya Pradesh ..	35	35	35	35	35	35	35	35	35	35	35	35
Maharashtra ..	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1
Gujarat ..	40	40	40	40	40	40	40	40	40	40	40	40
Rajasthan ..	1	1	1	1	1	1	1	1	1	1	1	1
Total ..	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1
VI. POWER POTENTIAL (in MW at 60 per cent L. F.)												
HIRANPHAL ..	330	364	394	428	..	..	..	..	..	..	..	..
JALSINDHI ..	258	266	275	288	595	658	707	757	..	..	..	..
NAVAGAM—River bed TWL+80 ..	134	143	154	169	176	196	212	228	594	640	674	725
Canal FSL+210 ..	..	..	..	..	..	..	..	..	306	319	333	350
Total ..	722	773	823	885	771	854	919	985	900	959	1007	1075
Less power for lift irrigation of 29 lakh acres in Gujarat and Rajasthan (Vide annexure XII-3)	160	160	160	160	160	160	160	160	160	160	160	160
NET ..	562	613	663	725	611	694	759	825	740	799	847	915

COMPARATIVE STUDY OF POWER GENERATION WITH IRRIGATION WITHDRAWALS 15·75 MAF NET AT THE END OF 20 YEARS FROM START

ALT. II NAVAGAM CANAL OFFTAKE LEVEL+300

	Combination I				Combination II				Combination III			
	Hiranphal +465 No Jalsindhi Navagam +320	Hiranphal +480 No Jalsindhi Navagam +320	Hiranphal +490 No Jalsindhi Navagam +320	Hiranphal +500 No Jalsindhi Navagam +320	No Hiranphal Jalsindhi +465 Navagam +320	No Hiranphal Jalsindhi +480 Navagam +320	No Hiranphal Jalsindhi +490 Navagam +320	No Hiranphal Jalsindhi +500 Navagam +320	No Hiranphal No Jalsindhi Navagam +465	No Hiranphal No Jalsindhi Navagam +480	No Hiranphal No Jalsindhi Navagam +490	No Hiranphal No Jalsindhi Navagam +500
	1	2	3	4	5	6	7	8	9	10	11	12
I. (*i*)Average annual flow at Navagam MAF ..	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94
(*ii*) Live aggregate storage at all storage sites in the entire basin. MAF	17·70	18·82	19·91	21·30	20·00	21·57	23·07	24·58	22·52	24·49	25·92	28·22
II. WATER UTILISATION MAF												
(*i*) Gross utilisation for irrigation and power ..	24·27	24·94	25·60	26·43	26·25	27·30	28·03	28·90	28·40	28·96	29·35	29·98
(*ii*) Gross utilisation expressed as percentage of average flow.	67·5	69·3	71·2	73·50	73·00	76·00	77·00	80·30	79·00	80·50	81·50	83·30
(*iii*) Net utilisation for irrigation—												
(A) in Madhya Pradesh ..	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25	7·25
(B) in Maharashtra ..	0.10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10
(C) in Gujarat ..	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15	8·15
(D) in Rajashthan ..	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25
TOTAL ..	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75	15·75
(*iv*) Evaporation losses ..	2·20	2·42	2·55	2·70	2·20	2·30	2·30	2·40	2·37	2·44	2·53	2·70
(*v*) Total consumptive use (irr. & eva. losses) II (*iii*)+II(*iv*).	17·95	18·17	18·30	18·45	17·95	18·05	18·05	18·15	18·12	18·19	18·28	18·45

III. Balance flowing to the sea I(*i*)—II(*v*) MAF ..	17·99	17·77	17·64	17·49	17·99	17·89	17·89	17·79	17·82	17·75	17·66	17·49
IV. (*i*) Utilisation for power generation at River bed power house at Navagam II(*i*)—II(*v*) MAF.	6·32	6·77	7·30	7·98	8·30	9·25	9·98	10·75	10·28	10·77	11·07	11·53
(*ii*) Water going to sea unutilised either for irrigation or power generation I(*i*)—II(*i*).	11·67	11·00	10·34	9·51	9·69	8·64	7·91	7·04	7·54	6·98	6·59	5·96
TOTAL ..	17·99	17·77	17·64	17·49	17·99	17·89	17·89	17·79	17·82	17·75	17·66	17·49
V. IRRIGATION (in akh acres)—												
(A) in Mad a Pradesh ..	35	35	35	35	35	35	35	35	35	35	35	35
(B) in Maharashtra ..	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1
(C) in Gujarat ..	40	40	40	40	40	40	40	40	40	40	40	40
(D) in Rajasthan ..	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL ..	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1	76·1
VI. POWER POTENTIAL (In MW at 60 per cent L.F.)												
HIRANPHAL ..	330	364	394	428	..	..	..	..	..	..	..	
JALSINDHI			..	..	302	347	382	420	..	..		..
NAVAGAM—River bed TWL+80 ..	248	266	287	314	326	363	392	422	594	640	674	725
Canal FSL+300 ..	..	..	..	..	..	..	..	..	182	196	209	226
TOTAL ..	578	630	681	742	628	710	774	842	776	826	883	951

COMPARATIVE STUDY OF POWER GENERATION WITH IRRIGATION WITHDRAWALS 23·80 MAF NET AT FULL DEVELOPMENT 30 YEARS FROM START ALT. I NAVAGAM CANAL OFFTAKE LEVEL+210

		Combination I				Combination II				Combination III			
	..	Hiranphal +465 Jalsindhi + 20 Navagam +210	Hiranphal +480 Jalsindhi + 320 Navagam +210	Hiranphal + 490 Jalsindhi + 320 Navagam +210	Hiranphal + 500 Jalsindhi + 320 Navagam +210	No Hiranphal Jalsindhi +465 Navagam + 210	No Hiranphal Jalsindhi +480 Navagam +210	No Hiranphal Jalsindhi + 490 Navagam +210	No Hiranphal Jalsindhi +500 Navagam +210	No Hiranphal No Jalsindhi Navagam +465	No Hiranphal No Jalsindhi Navagam +480	No Hiranphal No Jalsindhi Navagam + 490	No Hiranphal No Jalsindhi Navagam + 500
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
I. (*i*) Average annual flow at Navagam MAF	..	35·94	35·94	35·94	35·94	35·94	35·94	36·94	35·94	35·94	35·94	35·94	35·94
(*ii*) Live aggregate storage at all storage sites in the entire basin	..	17·70	18·82	19·91	21·30	20·00	21·57	23·07	24·58	22·52	24·49	25·92	28·22
II. WATER UTILISATION MAF													
(*i*) Gross utilisation for irrigation and power	..	25·09	25·76	26·42	27·25	27·05	28·05	28·66	29·25	28·85	29·39	29·78	30·40
(*ii*) Gross utilisation expressed as percentage of average flow.	..	69·8	71·7	73·5	75·9	75·2	77·8	79·8	81·3	80·3	81·5	82·8	84·5
(*iii*) Net utilisation for irrigation—													
(A) in Madhya Pradesh	..	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80
(B) in Maharashtra	..	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10
(C) in Gujarat	..	8·99	9·44	9·65	9·65	9·65	9·65	9·65	9·65	9·65	9·65	9·65	9·65
(D) in Rajasthan	..			0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25	0·25
TOTAL	..	22·89	23·34	23·80	23·80	23·80	23·80	23·80	23·80	23·80	23·80	23·80	23·80

(*iv*) Evaporation losses	..	2·20	2·42	2·55	2·70	2·20	2·30	2·30	2·40	2·37	2·44	2·53	2·70
(*v*) Total consumptive use (irr. & eva. losses) II *iii*+II *iv*.	..	25·09	25·76	26·35	26·50	26·00	26·10	26·10	26·10	26·17	26·24	26·33	26·50
III. BALANCE FLOWING TO THE SEA (I *i*—II *v*) MAF.	..	10·85	10·18	9·59	9·44	9·94	9·84	9·84	9·74	9·77	9·70	9·61	9·44
IV. (*i*) Utilisation for power generation at river bed power-house at Navagam (II *i*—II *v*) MAF.	..	..	..	0·07	0·75	1·05	1·95	2·56	3·05	2·68	3·15	3·45	3·90
(*ii*) Water going to sea unutilised either for irrigation or power generation I *i*—II *i* MAF		10·85	10·18	9·52	8·69	8·89	7·89	7·28	6·69	7·09	6·55	6·16	5·54
TOTAL	..	10·85	10·18	9·59	9·44	9·94	9·84	9·84	9·74	9·77	9·70	9·61	9·44
V. IRRIGATION (in lakh acres)	..												
(A) in Madhya Pradesh	..	65	65	65	65	65	65	65	65	65	65	65	65
(B) in Maharashtra	..	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1
(C) in Gujarat	..	40	43	45·8	45·8	45·8	45·8	45·8	45·8	45·8	45·8	45·8	45·8
(D) in Rajasthan	..	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0
TOTAL	..	106·1	109·1	111·9	111·9	111·9	111·9	111·9	111·9	111·9	111·9	111·9	111·9
VI. POWER POTENTIAL (in MW at 60 % L. F.)													
HIRANPHAL	..	199	224	247	275	..	..	..	..	..	..	..	..
JALSINDHI	..	155	163	172	185	386	436	474	507	..	..	..	..
NAVAGAM River bed TWL+80	..	..	..	..	16	22	41	54	65	154	187	210	245
Canal FSL+210	..	..	..	..	..	..	..	..	..	361	376	392	413
TOTAL	..	354	387	419	476	408	477	528	572	515	563	602	658
Less power for lift irrigation of 35 lakh acres in Gujarat and Rajasthan (Vide annexure XII-3).		160 (29 lakh acres.)	180 (32 lakh acres.)	200	200	200	200	200	200	200	200	200	200
NET	..	194	207	219	276	208	277	328	372	315	363	402	458

COMPARATIVE STUDY OF POWER GENERATION WITH IRRIGATION WITHDRAWALS 23·80 MAF NET AT FULL DEVELOPMENT 30 YEARS FROM START

ALT. II—NAVAGAM CANAL OFFTAKE LEVEL+300

	Combination I				Combination II				Combination III			
	Hiranphal +465 No Jalsindhi Navagam +320	Hiranphal +480 No Jalsindhi Navagam +320	Hiranphal +490 No Jalsindhi Navagam +320	Hiranphal +500 No Jalsindhi Navagam +320	No Hiranphal Jalsindhi +465 Navagam +320	No Hiranphal Jalsindhi +480 Navagam +320	No Hiranphal Jalsindhi +490 Navagam +320	No Hiranphal Jalsindhi +500 Navagam +320	No Hiranphal No Jalsindhi Navagam +460	No Hiranphal No Jalsindhi Navagam +480	No Hiranphal No Jalsindhi Navagam +490	No Hiranphal No Jalsindhi Navagam +500
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
I. (*i*) Average annual flow at Navagam MAF ..	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94	35·94
(*ii*) Live aggregate storage at all storage sites in the entire basin. ..	17·70	18·82	19·91	21·30	20·00	21·57	23·07	24·58	22·52	24·49	25·92	28·22
II. WATER UTILISATION MAF												
(*i*) Gross utilisation for Irrigation & Power ..	25·09	25·76	26·42	27·25	27·05	28·05	28·66	29·25	28·85	29·39	29·78	30·40
(*ii*) Gross utilisation expressed as percentage of average flow. ..	69·8	71·7	73·5	75·9	75·2	77·8	79·8	81·3	80·3	81·5	82·8	84·5
(*iii*) Net utilisation for irrigation												
(A) in Madhya Pradesh ..	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80	13·80
(B) in Maharashtra ..	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	0·10	01·0	0·10
(C) in Gujarat ..	8·99	9·44	9·65	9·65	9·65	9·65	9·65	9·65	9·65	9·65	9·65	9·65
(D) in Rajasthan ..			·25	·25	·25	·25	·25	·25	·25	·25	·25	·25
T TAL ..	22·89	23·34	23·80	23·80	23·80	23·80	23·80	23·80	23·80	23·80	23·80	23·80

(*iv*) Evaporation losses	..	2·20	2·42	2·55	2·70	2·20	2.30	2·30	2·40	2·37	2·44	2·53	2·70
(*v*) Total consumptive use (Irr. + Eva. losses) II (*iii*) +II (*iv*).		25·09	25·76	26·35	26·50	26·00	26·10	26·10	26·20	26·17	26·24	26·33	26·50
III. BALANCE FLOWING TO THE SEA (I *i*—II *v*) MAF		10·85	10·18	9·59	9·44	9·94	9·84	9·84	9·74	9.77	9.70	9.61	9·44
IV. (*i*) Utilisation for power generation at river bed power house at Navagam (II*i*—II*v*) MAF		..	..	0·07	0·75	1·05	1·95	2·56	3·05	2·68	3·15	3·45	3·90
(*ii*) Water going to sea unutilised either for irrigation or power generation (I*i*—II*i*) MAF		10·85	10·18	9·52	8·69	8·89	7·89	7·28	6·69	7·09	6·55	6·16	5·54
TOTAL	..	10·85	10·18	9·59	9·44	9·94	9·84	9·84	9·74	9·77	9·70	9·61	9·44
V. IRRIGATION (in lakh acres)	..												
(A) in Madhya Pradesh	..	65	65	65	65	65	65	65	65	65	65	65	65
(B) in Maharashtra	..	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1
(C) in Gujarat	..	40.	43.	45·8	45·8	45·8	45·8	45·8	45·8	45·8	45·8	45·8	45·8
(D) in Rajasthan	..	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0
TOTAL	..	106·1	109·1	111·9	111·9	111·9	111·9	111·9	111·9	111·9	111·9	111·9	111·9
VI· POWER POTENTIAL (in MW at 60 per cent L.F.)													
Hiranphal	..	199	224	247	275	..	..	..	..	..	..	..	..
Jalsindhi	..	..	..	..	..	195	230	255	281	..	..	..	..
Navagam River bed TWL+80	..	..	..	..	29	41	76	100	120	154	187	210	245
Canal FSL+300	..	..	..	..	..	..	..	..	..	215	232	246	266
TOTAL	..	199	224	247	304	236	306	355	401	369	419	456	511

ANNEXURE XII-2 (E)

PLANWISE POWER POTENTIALS IN MW AT 60% L. F. OF PROJECTS IN MADHYA PRADESH AND NAVA GAM WITH IRRIGATION WITHDRAWALS OF 23·80 MAF NET ON FULL DEVELOPMENT 30 YEARS FROM START WITH NAVAGAM FRL+500 AND CANAL FSL+300.

STATEWISE IRRIGATION —

M.P.	13·80	MAF
Mah.	·10	,,
Guj.	9·65	,,
Raj.	0·25	,,

4th PLAN (1965—70)	5th PLAN (1970—75)	6th PLAN (1975—80)	7th PLAN (1980—85)	8th PLAN (1985—90)	9th PLAN (1990—95)
	Total irrigation withdrawal in M. P. 2·0 MAF	Total irrigation withdrawals in M.P. 4·0 MAF	Total irrigation withdrawals in M.P. 7·25 MAF	Total irrigation withdrawals in M.P. 10·5 MAF	Total irrigation withdrawals in M. P. 13·80 MAF
Nil (Construction Period)	(Up to Bargi .. 1·0	(Between Basania and Bargi .. 2·0	(Between Basania and Bargi .. 2·0	(Between Basania and Bargi .. 3·0	(Between Basania and Bargi .. 3·0
	Tawa .. 1·0	Tawa .. 1·26 Up to Punasa .. 0·74)	Tawa .. 1·26 Up to Punasa .. 3·09	Tawa .. 1·26 Up to Punasa .. 5·34	Tawa .. 1·26 Up to Punasa .. 6·64
			Barwaha .. 0·90	Barwaha .. 0·90)	Barwaha .. 2·90
					This includes 1·92 MAF for Minor Schemes.
	Rosra	Rosra .. 52	Rosra .. 52	Rosra .. 52	Rosra .. 52
	Burhner	Burhner .. 28	Burhner .. 28	Burhner .. 28	Burhner .. 28
	Basania	Basania .. 60	Basania .. 60	Basania .. 60	Basania .. 60
	Bargi .. 70 (without storage U/S)	Bargi .. 100 (with storage U/S).	Bargi .. 100	Bargi .. 74	Bargi .. 74
	Chinki	Chinki .. 55	Chinki .. 55	Chinki .. 40	Chinki .. 40
	Sitarewa	Sitarewa .. 11	Sitarewa .. 11	Sitarewa .. 11	Sitarewa .. 11
	Hoshangabad	Hoshangabad .. 50	Hoshangabad .. 50	Hoshangabad .. 37	Hoshangabad .. 37
	Tawa .. 20	Tawa .. 20	Tawa .. 20	Tawa .. 20	Tawa .. 20
	Punasa .. 464	Punasa .. 522	Punasa .. 446	Punasa .. 342	Punasa .. 333
	(Net utilisation 16·5 MAF less irr. abst. 2 MAF)	(Net utilisation 20·3 MAF less irrig. abstr. 4·0).	(Net utilisation 20·3 MAF less irr. abs. 6·35 MAF).	(Net utilisation 20·3 MAF less irr. abs. 9·6 MAF)	(Net utilisation 21·3 MAF (less irr. abs. 10·9 MAF)

Barwaha	Barwaha (lift dam) .. 300 (Utilisation 16·5 MAF)	Barwaha .. 241 (Net utilisation 13·95 MAF less irr. 0·9 MAF).	Barwaha .. 181 (Net utilisation 10·7 MAF less irr. 0·9 MAF)	Barwaha .. 138 (Net utilisation 10·4 MAF less irr. abs. 2·9 MAF)
TOTAL .. 554	TOTAL ..1198	TOTAL ..1063	TOTAL .. 843	TOTAL .. 793
Total irr. abs. in Gujarat & Raj. 2·0 MAF.	Total irr. abs. in Gujarat & Raj. 5·2 MAF.	Total irr. abs. in Gujarat & Raj 8·4 MAF.	Total irr abs. in Gujarat & Raj. 9·9. MAF.	Total irr. abs. in Gujarat & Raj. 9·9 MAF.
(Maharashtra irr. abs. 0·1 MAF)	(Maharashtra 0·1 MAF)	(Maharashtra 0·1 MAF)	(Maharashtra 0·1 MAF)	(Maharashtra 0·1 MAF)
NAVAGAM—	**NAVAGAM—**	**NAVAGAM—**	**NAVAGAM—**	**NAVAGAM—**
River bed p.h. ..1000*	River bed p.h. ..1000†	River bed p.h. .. 725	River bed p.h. .. 430	River bed p.h. 245
(Net utilisation 26·35 MAF. less irr.abs. 4·1 MAF)	(Net utilisation 27·19 MAF. less irr. abs. 9·3 MAF)	(Net utilisation 27·28 MAF. less irr abs.15·75 MAF)	(Net utilisation 27·35 MAF. less irr. abs. 20·50 MAF)	(Net utilisation 27·70 MAF. less irr. abs. 23·80 MAF)
Canal (FSL+300) p.h. 54 (utilisation 2 MAF).	Canal (FSL+300) p.h. 140 (utilisation 5·2 MAF)	Canal (FSL+300) p.h. 226 (utilisation 8·4 MAF)	Canal (FSL+300) p.h. 266 (utilisation 9·9 MAF)	Canal (FSL+300) p.h. 266 (utilisation 9·9 MAF)
NAVAGAM TOTAL ..1054	NAVAGAM TOTAL ..1140	NAVAGAM TOTAL .. 951	NAVAGAM TOTAL .. 696	NAVAGAM TOTAL 511
GRAND TOTAL ..1608	GRAND TOTAL ..2338	GRAND TOTAL ..2014	GRAND TOTAL ..1539	GRAND TOTAL 1304

* at 84% L. F. as capacity restricted by installation of 1000 MW.

† at 68% L. F. as capacity restricted by installation of 1000 MW.

EXPLANATIONS TO THE TABLES IN ANNEXURE XII-2

The gross utilisation figures given in these tables are taken from the results of the mass curve studies. The mass curves prepared for Navagam and Hiranphal are appended to this annexure (plates XII. 1 to 4).

The mass curves are based on the following data:—

(*i*) Monthly runoff figures for the zonal computations with 0·85 reduction co-efficient for the period 1915—62. The figures for Hiranphal and Navagam sites are given in tables XII-2 (A) and XII-2 (B) respectively.

(*ii*) Total irrigation requirements and the monthly abstractions in Madhya Pradesh, Maharashtra, Gujarat and Rajasthan as given in tables 7·9 and 7·10 of Chapter VII.

(*iii*) Effective storages upto Punasa in Madhya Pradesh are taken as follows :—

Rosra	..	1.95 MAF
Burhner	..	1·56 MAF
Bargi	..	2·81 MAF
Tawa	..	2·26 MAF
Punasa (FRL+860)	..	8·40 MAF
Total		16·98 say 17·0 MAF

The storages at Hiranphal, Jalsindhi and Navagam for different reservoir levels as given in table 12·4 of Chapter XII.

(*iv*) Availability is taken as 90 per cent. Out of 48 years, supplies to power is cut in only 4 bad years.

As given in Table 7·9 Madhya Pradesh irrigation requirement of 13·80 MAF includes minor schemes utilising 1·92 MAF. For the purpose of mass curves the quantity of 1·92 MAF is assumed to be stored in four monsoon months and the balance requirement forms an integrated system. Thus two mass curves are prepared for each site with irrigation abstractions of 11·88 MAF and 13·8 MAF up to Hiranphal and 21·88 MAF and 23·8 MAF upto Navagam. The monthly abstractions for irrigation with 13·80 MAF and 23·8 MAF are taken as follows for the purpose of mass curves—

Hiranphal—Total 13·80 MAF

January	February	March	April	May	June	July	August	September	October	November	December
1·42	0·20	0·26	0·48	1·00	1·18	0·94	1·49	2·52	1·13	1·59	1·59

Navagam—Total 23·80 MAF

January	February	March	April	May	June	July	August	September	October	November	December
1·90	0·34	0·58	0·91	1·83	2·73	2·34	1·99	3·71	2·30	2·58	2·59

As the Jalsindhi runoff is nearly the same as Navagam, separate mass curve is not prepared for this site. Gross utilization figures for this site are taken from Navagam mass curves with slight adjustment for the runoff.

At Navagam site, utilization of 0·4 MAF is added to the figures of utilization with the storage dams at Hiranphal, and at Jalsindhi, as the runoff below these dams is expected to be utilised to this extent for irrigation during monsoon months from Navagam Dam.

Utilization for power, and power generated at Hiranphal and Navagam during various stages of development are given in Table XII-2 (C).

Power developed at various power stations in the Narmada basin during various stages of development is given in annexure XII-2 (E).

It would be seen from these tables that the regeneration flow has not been taken into account for power computations.

TABLE XII-2 (A)

NARMADA AT HIRANPHAL

MONTHLY RUNOFF BASED ON ZONAL STUDIES WITH 0·85 REDUCTION CO-EFFICIENT

Sl. No.	Year	Annual Runoff (MAF)	January 0·010335	February 0·007110	March ·005238	April ·003780	May ·002391	June ·012501	July ·147594	August ·312430	September ·357156	October 0·099583	November ·028136	December ·013746
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1.	1915 ..	37·93	0·39	0·27	0·20	0·14	0·09	0·47	5·60	11·85	13·55	3·78	1·07	0·52
2.	1916 ..	42·77	0·44	0·30	0·22	0·16	0·10	0·53	6·32	13·36	15·28	4·27	1·20	0·59
3.	1917 ..	47·05	0·49	0·33	0·25	0·18	0·11	0·59	6·94	14·70	16·80	4·69	1·32	0·65
4.	1918 ..	14·07	0·15	0·10	0·07	0·05	0·03	0·18	2·08	4·40	5·02	1·40	0·40	0·19
5.	1919 ..	48·08	0·50	0·34	0·25	0·18	0·12	0·60	7·10	15·02	17·18	4·78	1·35	0·66
6.	1920 ..	18·85	0·19	0·13	0·10	0·07	0·05	0·24	2·78	5·88	6·74	1·88	0·53	0·26
7.	1921 ..	27·02	0·28	0·19	0·14	0·10	0·06	0·34	3·98	8·44	9·69	2·68	0·75	0·37
8.	1922 ..	26·88	0·28	0·19	0·14	0·10	0·06	0·33	3·98	8·34	9·51	2·65	0·74	0·36
9.	1923 ..	41·15	0·43	0·29	0·22	0·16	0·10	0·51	6·08	12·86	14·70	4·09	1·15	0·56
10.	1924 ..	31·60	0·33	0·22	0·17	0·12	0·08	0·39	4·66	9·86	11·30	3·16	0·88	0·43
11.	1925 ..	24·87	0·26	0·18	0·13	0·09	0·06	0·31	3·67	7·77	8·88	2·48	0·70	0·34
12.	1926 ..	43·41	0·45	0·31	0·23	0·16	0·10	0·54	6·40	13·55	15·52	4·33	1·22	0·60
13.	1927 ..	27·68	0·29	0·20	0·14	0·10	0·07	0·35	4·08	8·65	9·89	2·76	0·77	0·38

14.	1928	..	29·35	0·30	0·21	0·15	0·11	0·07	0·37	4·34	9·17	10·49	2·92	0·82	0·40
15.	1929	..	27·35	0·28	0·19	0·14	0·10	0·07	0·34	4·04	8·55	9·76	2·73	0·77	0·38
16.	1930	..	32·25	0·33	0·23	0·17	0·12	0·08	0·40	4·76	10·09	11·50	3·22	0·91	0·44
17.	1931	..	43·19	0·45	0·31	0·23	0·16	0·10	0·54	6·37	13·50	15·42	4·31	1·21	0·59
18.	1932	..	33·03	0·34	0·23	0·17	0·12	0·08	0·41	4·87	10·32	11·82	3·29	0·93	0·45
19.	1933	..	44·43	0·46	0·32	0·23	0·17	0·11	0·56	6·55	13·89	15·86	4·42	1·25	0·61
20.	1934	..	42·00	0·43	0·30	0·22	0·16	0·10	0·53	6·20	13·12	15·01	4·18	1·18	0·57
21.	1935	..	28·39	0·29	0·20	0·15	0·11	0·07	0·35	4·19	8·87	10·14	2·83	0·80	0·39
22.	1936	..	38·02	0·39	0·27	0·20	0·14	0·09	0·48	5·61	11·88	13·58	3·79	1·07	0·52
23.	1937	..	39·92	0·41	0·28	0·21	0·15	0·10	0·50	5·89	12·47	14·26	3·98	1·12	0·55
24.	1938	..	39·23	0·41	0·28	0·21	0·15	0·09	0·49	5·79	12·26	14·01	3·90	1·10	0·54
25.	1939	..	32·41	0·33	0·23	0·17	0·12	0·08	0·40	4·78	10·13	11·58	3·23	0·91	0·45
26.	1940	..	36·35	0·38	0·26	0·19	0·14	0·09	0·45	5·36	11·36	12·98	3·62	1·02	0·50
27.	1941	..	15·00	0·16	0·11	0·08	0·06	0·04	0·19	2·20	4·69	5·36	1·48	0·42	0·21
28.	1942	..	43·76	0·45	0·31	0·23	0·17	0·10	0·55	6·46	13·67	15·63	4·36	1·23	0·69
29.	1943	..	38·43	0·40	0·27	0·20	0·15	0·09	0·48	5·67	12·00	13·73	3·83	1·08	0·53
30.	1944	..	57·35	0·59	0·41	0·30	0·22	0·14	0·72	8·46	17·92	20·48	5·71	1·61	0·79
31.	1945	..	35·59	0·37	0·26	0·19	0·13	0·09	0·44	5·25	11·12	12·71	3·54	1·00	0·49
32.	1946	..	41·71	0·43	0·30	0·22	0·16	0·10	0·52	6·16	13·03	14·90	4·15	1·17	0·57
33.	1947	..	39·44	0·41	0·28	0·21	0·15	0·09	0·49	5·82	12·32	14·09	3·93	1·11	0·54
34.	1948	..	41·62	0·43	0·30	0·22	0·16	0·10	0·52	6·14	13·00	14·86	4·14	1·18	0·57

Sl. No.	Year		Annual Runoff (MAF)	January ·010335	February ·007110	March ·005238	April ·003780	May ·002391	June ·012501	July ·147594	August ·312430	September ·357156	October ·099583	November ·028136	December ·013746
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
35.	1949	..	33·00	0·34	0·23	0·17	0·12	0·08	0·42	4·87	10·31	11·79	3·29	0·93	0·45
36.	1950	..	28·91	0·30	0·21	0·15	0·11	0·07	0·36	4·27	9·03	10·33	2·88	0·80	0·40
37.	1951	..	17·62	0·18	0·13	0·09	0·07	0·04	0·22	2·60	5·51	6·29	1·75	0·50	0·24
38.	1952	..	18·76	0·19	0·13	0·10	0·07	0·04	0·23	2·77	5·86	6·70	1·88	0·53	0·26
39.	1953	..	22·71	0·23	0·16	0·13	0·09	0·05	0·28	3·35	7·10	8·11	2·26	0·64	0·31
40.	1954	..	31·83	0·33	0·23	0·17	0·12	0·08	0·40	4·70	9·93	11·36	3·17	0·90	0·44
41.	1955	..	40·93	0·42	0·29	0·21	0·15	0·10	0·51	6·04	12·79	14·63	4·08	1·15	0·56
42.	1956	..	36·56	0·38	0·26	0·19	0.14	0·09	0·46	5·40	11·41	13·06	3·64	1·03	0·50
43.	1957	..	21·53	0·22	0·15	0·11	0·08	0·05	0·27	3·18	6·73	7·69	2·14	0·61	0·30
44.	1958	..	31·34	0·32	0·22	0·16	0·12	0·07	0·39	4·64	9·79	11·19	3·13	0·88	0·43
45.	1959	..	41·43	0·43	0·29	0·22	0·16	0·10	0·52	6·10	12·94	14·80	4·13	1·17	0·57
46.	1960	..	27·10	0·28	0·19	0·14	0·10	0·06	0·34	4·00	8·48	9·68	2·70	0·76	0·37
47.	1961	..	55·06	0·57	0·39	0·29	0·21	0·13	0·69	8·12	17·20	19·67	5·48	1·55	0·76
48.	1962	..	25·83	0·27	0·18	0·14	0·10	0·06	0·32	3·80	8·07	9·23	2·57	0·73	0·36

TABLE XII-2 (B

NARMADA AT NAVAGAM

MONTHLY RUNOFFS BASED ON ZONAL STUDIES WITH 0·85 REDUCTION CO-EFFICIENT

Year (1)	Annual Runoff (MAF) (2)	January ·010335 (3)	February 0·007110 (4)	March ·005238 (5)	April ·005238 (6)	May ·002391 (7)	June ·012501 (8)	July ·147594 (9)	August ·312430 (10)	September ·357156 (11)	October ·099583 (12)	November ·028136 (13)	December ·013746 (14)
1915 ..	39·41	0·41	0·28	0·21	0·15	0·09	0·49	5·82	12·31	14·08	3·92	1·11	0·54
1916 ..	44·69	0·46	0·32	0·23	0·17	0·11	0·56	6·60	13·96	15·96	4·45	1·26	0·61
1917 ..	49·45	0·51	0·35	0·26	0·19	0·12	0·62	7·30	15·45	17·66	4·92	1·39	0·68
1918 ..	14·07	0·15	0·10	0·07	0·05	0·03	0·18	2·08	4·40	5·02	1·40	0·40	0·19
1919 ..	51·09	0·53	0·36	0·27	0·19	0·12	0·64	7·54	15·96	18·25	5·09	11·44	0·70
1920 ..	20·48	0·21	0·15	0·11	0·08	0·05	0·26	3·02	6·40	7·30	2·04	0·58	0·28
1921 ..	28·82	0·30	0·20	0·15	0·11	0·07	0·36	4·25	9·00	10·30	2·87	0·81	0·40
1922 ..	27·68	0·29	0·20	0·14	0·10	0·07	0·35	4·09	8·64	9·88	2·76	0·78	0·38
1923 ..	42·42	0·44	0·30	0·22	0·16	0·10	0·53	6·26	13·26	15·16	4·22	1·19	0·58
1924 ..	33·56	0·35	0·28	0·18	0·13	0·08	0·42	4·95	10·48	11·97	3·34	0·94	0·44
1925 ..	25·40	0·26	0·18	0·13	0·10	0·06	0·32	3·75	7·94	9·07	2·53	0·71	0·35
1926 ..	44·42	0·46	0·32	0·23	0·17	0·11	0·56	6·56	13·88	15·85	4·42	1·25	0·61
1927 ..	29·62	0·31	0·21	0·16	0·11	0·07	0·37	4·37	9·25	10·58	2·95	0·83	0·41
1928 ..	30·92	0·32	0·22	0·16	0·12	0·07	0·39	4·56	9·65	11·03	3·08	0·87	0·45
1929 ..	28·09	0·30	0·21	0·15	0·11	0·07	0·36	4·14	8·78	10·00	2·80	0·79	0·38

Year	Annual Runoff (MAF)	January ·010335	February ·007110	March ·005238	April ·003780	May ·002391	June ·012501	July ·147594	August ·312430	September ·357556	October ·099583	November ·028136	December ·013746
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1930 ..	34·17	0·35	0·24	0·18	0·13	0·08	0·43	5·04	10·68	12·21	3·40	0·96	0·47
1931 ..	45·90	0·47	0·33	0·24	0·17	0·11	0·57	6·77	14·35	16·40	4·57	1·29	0·63
1932 ..	34·96	0·36	0·25	0·18	0·13	0·08	0·44	5·16	10·92	12·50	3·48	0·98	0·48
1933 ..	47·53	0·49	0·34	0·25	0·18	0·11	0·59	7·02	14·85	16·98	4·73	1·34	0·65
1934 ..	43·77	0·45	0·31	0·23	0·17	0·10	0·55	6·46	13·68	15·63	4·36	1·23	0·60
1935 ..	29·32	0·30	0·21	0·15	0·11	0·07	0·37	4·33	9·16	10·48	2·92	0·82	0·40
1936 ..	39·30	0·41	0·28	0·21	0·15	0·09	0·49	5·80	12·28	14·03	3·91	1·11	0·54
1937 ..	41·41	0·43	0·29	0·22	0·16	0·10	0·52	6·11	12·94	14·80	4·12	1·15	0·57
1938 ..	41·03	0·42	0·29	0·21	0·16	0·10	0·51	6·06	12·82	14·66	4·09	1·15	0·56
1939 ..	33·27	0·34	0·24	0·17	0·13	0·08	0·42	4·91	10·39	11·88	3·31	0·94	0·46
1940 ..	38·18	0·39	0·27	0·20	0·14	0·09	0·48	5·64	11·93	13·65	3·80	1·07	0·52
1941 ..	15·95	0·16	0·11	0·08	0·06	0·04	0·20	2·35	4·98	5·71	1·59	0·45	0·22
1942 ..	45·96	0·47	0·33	0·24	0·17	0·11	0·57	6·78	14·37	16·42	4·58	1·29	0·63
1943 ..	40·02	0·41	0·28	0·21	0·15	0·10	0·50	5·91	12·50	14·29	3·99	1·13	0·55
1944 ..	60·84	0·63	0·43	0·32	0·23	0·15	0·76	8·99	19·00	21·72	6·06	1·71	0·84
1945 ..	37·44	0·39	0·27	0·20	0·14	0·09	0·47	5·53	11·70	13·36	3·73	1·05	0·51

1946	..	44·40	0·46	0·32	0·23	0·17	0·11	0·56	6·55	13·87	15·85	4·42	1·25	0·61
1947	..	40·94	0·42	0·29	0·21	0·15	0·10	0·51	6·04	12·80	14·63	4·08	1·15	0·56
1948	..	43·54	0·45	0·31	0·23	0·16	0·10	0·54	6·43	13.60	15·55	4·34	1·23	0·60
1949	..	34·62	0·36	0·25	0·18	0·13	0·08	0·43	5·11	10·82	12·36	3·45	0·97	0·48
1950	..	30·79	0·32	0·22	0·16	0·12	0·07	0·38	4·54	9·62	11·00	3·07	0·87	0·42
1951	..	18·32	0·19	0·13	0·10	0·07	0·04	0·23	2·70	5·72	6·55	1·82	0·52	0·25
1952	..	19·11	0·20	0·14	0·10	0·07	0·05	0·24	2·82	5·97	6·82	1·90	0·54	0·26
1953	..	23·97	0·25	0·17	0·13	0·09	0·06	0·30	3·54	7·49	8·55	2·39	0·67	0·33
1954	..	34·50	0·36	0·25	0·18	0·13	0·08	0·43	5·09	10·78	12·31	3·45	0·97	0·47
1955	..	42·93	0·44	0·31	0·22	0·16	0·10	0·54	6·34	13·41	15·33	4·28	1·21	0·59
1956	..	38·61	0·40	0·27	0·20	0·15	0·09	0·48	5·70	12·06	13·80	3·84	1·09	0·53
1957	..	22·65	0·23	0·16	0·12	0·09	0·05	0·28	3·34	7·08	8·09	2·26	0·64	0·31
1958	..	33·86	0·35	0·24	0·18	0·13	0·08	0·42	5·00	10·58	12·09	3·37	0·95	0·47
1959	..	44·84	0·46	0·32	0·23	0·17	0·11	0·56	6·62	14·01	16·01	4·47	1·26	0·62
1960	..	28·15	0·29	0·20	0·15	0·11	0·07	0·35	4·15	8·79	10·06	2·80	0·79	0·39
1961	..	57·61	0·60	0·41	0·30	0·22	0·14	0·72	8·50	18·00	20·59	5·74	1·62	0·77
1962	..	27·32	0·28	0·19	0·14	0·10	0·07	0·34	4·02	8·54	9·77	2·72	0·77	0·38

TABLE XII-2 (C)

POWER GENERATION AT HIRANPHAL AND NAVAGAM DURING DIFFERENT STAGES OF DEVELOPMENT

Irrigation and power development in the States of Madhya Pradesh and Gujarat during the course of 30 years is given in Annexure XIII·2. Based on this development, the gross utilisation for irrigation and power and power generated is computed in the following table.

Development period from start	Gross Utilisation MAF	Evaporation loss MAF	Irrigation abstraction MAF	Net utilisation for power MAF	Power generated	
					MW at 60% L.F.	MW at 100% L.F.
Hiranphal FRL+465						
10 years ..	21·72	1·80	2·00	17·92	411	247
15 years ..	23·84	2·20	4·00	17·64	405	243
20 years ..	23·87	2·20	7·25	14·42	330	198
25 years ..	23·90	2·20	10·50	11·20	256	154
30 years ..	24·69	2·20	13·80	8·69	199	119
Hiranphal FRL+500						
10 years ..	23·88	2·20	2·00	19·68	524	314
15 years ..	26·00	2·70	4·00	19·30	514	308
20 years ..	26·03	2·70	7·25	16·08	428	259
25 years ..	26·07	2·70	10·50	12·87	342	205
30 years ..	26·85	2·70	13·80	10·35	275	159
Navagam FRL+465					River bed + Canal FSL+300	River bed + Canal FSL+300
10 years ..	25·85	2·10	4·1	19·65	1000* + 43	680 + 26
15 years ..	28·15	2·37	9·3	16·48	950 + 113	570 + 68
20 years ..	28·40	2·37	15·75	10·28	594 + 182	296 + 109
25 years ..	28·50	2·37	20·50	5·63	324 + 215	194 + 129
30 years ..	28·85	2·37	23·80	2·68	154 + 215	92 + 129
Navagam FRL+500						
10 years ..	28·85	2·50	4·1	22·25	1000* + 54	840 + 32
15 years ..	29·89	2·70	9·3	17·89	1000 + 140	678 + 84
20 years ..	29·98	2·70	15·75	11·53	725 + 226	435 + 135
25 years ..	30·05	2·70	20·50	6·85	430 + 266	258 + 160
30 years ..	30·40	2·70	23·80	3·90	245 + 266	147 + 160

* Power at 60% L. F. is restricted to 1000 WM because of the installed capacity of 1000 MW.

ANNEXURE XII-3

POWER REQUIREMENT TO IRRIGATE AREAS BETWEEN FSL+185/190 AND FSL +300 CANALS

The gross command under irrigation by FSL+185/190 canal has been assessed as 21·1 lakh acres by flow and 66·5 lakh acres by lift out of the gross area of 87·6 lakh acres.

Against the above gross command, the area proposed to be irrigated is 34·74 lakh acres and allowing the same ratio as for gross command, the area under flow irrigation will be 8·34 lakh acres and area under lift irrigation will be 26·40 lakh acres. Allowing that irrigation can be done with greater intensity under the low level canal command and that about 33 per cent of the Mahi command be irrigated by this canal, the total area under flow irrigation can be taken as about 12 lakh acres.

The total area proposed to be irrigated by the Navagam FSL+300 canal is as under—

(*i*) As proposed by Gujarat including area in Little Rann of Kutch.	34·74 lakh	acres
(*ii*) Area under Mahi command (proposed to be transferred to Navagam canal).	6·57 lakh	acres
(*iii*) Area in Great Rann of Kutch ..	4·50 lakh	acres
Total ..	45·81	
Say ..	45·8 lakh	acres

It is proposed to utilise Mahi waters for irrigation in Rajasthan areas bordering Pakistan and also in Gujarat areas above FSL+300 canal. These waters will not, therefore, be available to irrigate areas in Gujarat between FSL+185/190 and FSL+300 canals, and these areas will have to be provided with irrigation facilities from Narmada waters.

With 12 lakh acres of area under flow irrigation, the area under lift irrigation will be (45·8–12·0=) 33·8 lakh acres. Based on crop pattern and delta suggested by the Committee (para. 7·18 Chapter VII), the total water requirements for the lift area will be 7·35 MAF to be pumped through a height of 110 ft.

Average power requirement for this will be $\frac{7{\cdot}35 \times 1380 \times 110}{10} = 112$ MW at 100 per cent L. F.

The maximum water requirement will be in the month of June, being 1·50 MAF for the entire area of 45·8 lakh acres (Table 7·10 of Chapter VII). The water requirement for the lift area will be 1·10 MAF for that month. Allowing 0·035 MAF for June, for irrigating Rajasthan areas, the total water requirement for the month will be 1·135 MAF. The maximum power requirement will then be—

$$\frac{1{\cdot}135 \times 10^6 \times 110}{59{\cdot}5 \times 10} = 209 \text{ or Say 200 MW at 100 per cent L.F.}$$

ANNEXURE XII-4

NARMADA VALLEY DEVELOPMENT REQUIREMENTS OF STORAGE FOR FIXING OPTIMUM HEIGHT OF NAVAGAM DAM.

1·1 The average inflow at the Navagam dam site where the Narmada drains a catchment of 33,800 sq. miles out of its total catchment of about 38,000 sq. miles, has been estimated at 35·94 MAF on the basis of runoff data for the period from 1915 to 1962, the maximum being 60·84 MAF (1944) and the minimum, 14·07 MAF (1918). Ignoring any runoff in excess of this average of 35·94 MAF, which will in any case, run waste to sea, the average runoff works out to 31·71 MAF. The natural flow of the river for 90 per cent of the time is about 22·6 MAF. No doubt, as much water as possible should be used in the interest of irrigation. The balance water is proposed to be used for power generation. In this context the supply available or that can be made available on the usual availability of about 90 per cent of the time, are of special importance. From Table 5·10, it would be seen that there are considerable variations in the inflow from year to year, indicating that for a higher degree of unutilization, storages would be required both for regulation of seasonal variations in inflow of dependable years, as well as to even out the year to year fluctuations in inflow, through carry over operation.

1·2 For assessment of optimum development of the water resources of the river for irrigation and power, it would be necessary to arrive at the storage requirements in the entire valley for different utilisations. Although the Narmada provides a number of sites suitable for construction of dams, commensurately large storage capacity is obtainable only at a few sites like Bargi, Punasa, Hiranphal and Navagam. There are a few supplementary sites at Tawa, Rosra and Burhner with lower, but none-the-less important storage characteristics. Ideally, an assessment of the total storage for optimum development of the entire resources of the valley, would have to be done taking the inflows at every point of regulation/diversion and the impact of regulation and abstractions at these points, allowing, in detail, for the requirements of irrigation. However, in the Narmada valley where irrigation yet to be commenced and where gross potentialities in this regard have only been broadly indicated such a "micro" approach would not be realistic at this stage. This is also not essentail, since the main upstream storage sites at Punasa, Tawa and Bargi have already been investigated in detail and their economic limits fixed with fair certainty. It would therefore suffice to conduct studies to assess the total storage requirements and arrive at the residual storages at the terminal point, allowing for the possible upstream developments. The results obtained from such an approach are not likely to be significantly different from a detailed "micro" study, and if anything, would be conservative, in view of the fact that the storages already fixed for optimum development at Punasa, Tawa and Bargi, enable a gross utilisation corresponding to about 70 per cent of the average yield at Punasa, indicating a relatively low degree of carryover.

1·3 Accordingly, general studies have been carried out with mass curves for the total flows at Navagam—being the terminal development for the entire basin. A curve showing the gross utilisation of water that can be obtained for different effective storages in the valley, based on the above studies for the period from 1915 to 1962, is at Plate XII-5. The utilisation indicated therein would have an availability of about 90 per cent as is desirable from the point of view of firm power generation. It would be seen therefrom that the gross utilisation generally increases with higher storage. There is a significant proportionate increase up to a storage of about 28 MAF, and beyond about 30 MAF, the increase in utilisation shows a downward trend. The increase in utilisation for further increases in storage is much less as compared with the additional storage required. For instance, the additional gross utilisation per MAF of additional storage, is about 0·3 MAF at the point of 30 MAF total storage whereas it reduces to about 0·2 MAF up to a total storage of 45 MAF and is only about 0·1 MAF beyond. The actual net utilisation at the higher storages would be even less when losses due to evaporation are considered, since the losses would be much higher at higher storage levels where the area of spread of the reservoirs would be greater. On considerations of the trend of increase in benefits, an effective storage of the order of 28 to 30 MAF enabling a utilisation corresponding to about 83 per cent of average flow of the river, would appear to be the optimum that is required to be provided at the

potential sites in the entire Narmada valley. This is also borne out by the economic studies of the various storage schemes proposed in the valley, as discussed in paras. 1·4 and 1·5 below.

1·4 As already explained in para. 1·2 above, the main storage sites at Punasa (8·4 MAF effective), Tawa (2·26 MAF effective) and Bargi (2·8 MAF effective) have already been investigated and their economic storages fixed. The Tawa project is currently under construction. All these schemes together would afford an aggregate effective storage of about 13·5 MAF. In addition to these, two important irrigation schemes, viz., Barna and Kolar projects have also been investigated and the Barna project is currently under construction. The supplementary storage sites at Rosra and Burhner, which are still to be investigated, are expected to afford a total effective storage of about 3·5 MAF. Thus, a total storage of about 17 MAF would be available at the various sites at and upstream of Punasa in Madhya Pradesh and a major part of this storage has already been determined for optimum development. The balance storage required would therefore have to be provided at Navagam. The corresponding level at Navagam for providing the residual storage to make up an aggregate storage of 28 to 30 MAF in the entire valley is +500/+510 —over the minimum DDL of +370. This minimum drawn down level has been fixed to provide the minimum head for power generation at the canal power house.

1·5 In order to fix the optimum level of storage at Navagam, economic studies have been made for different FRLs from +465 to +530, which corresponds to a total storage in the entire valley ranging from about 22 MAF to about 36 MAF. The maximum irrigation utilisation proposed is 23·80 MAF (exclusive of evaporation losses), which can fully be met with the storage at +465 at Navagam.

The additional benefit to be evaluated at higher FRLs would, therefore, be in respect of the power potential apart from increased contributions to carryover capacity and flood control. Accordingly, the power potential at Navagam for the reservoir levels of +465, +480, +490, +500, +510, +520 and +530 have been worked out. Two power stations have been envisaged; one located at the canal head, utilising the waters released for irrigation from Navagam dam for irrigation in Gujarat and Rajasthan, and tailracing into the main canal with FSL +300 ft., and the second in the river bed, at the toe of the dam, utilising the waters surplus to irrigation and tailracing into the river at a level +80 ft.

The power potentials for the representative year 1985 (Annexure XIII-1) are given in the table below:—

FRL of Navagam	Net Utilisation MAF	Power MW at 60 per cent LF		
		River bed power	Canal power house	Total power MW at 60 per cent LF
+465	26·03	594	182	776
+480	26·52	640	196	836
+490	26·82	674	209	883
+500	27·28	725	226	951
+510	27·70	768	238	1006
+520	28·19	820	253	1073
+530	28·78	871	267	1138

The cost of the dam, including the cost of the submergence and overheads, for the FRLs indicated above has been estimated and the allocation to power as explained in Annexure XIII-1 is given below:—

FRL	Cost of Dam & appurtenant works including submergence & overheads	Allocation to power
	(Rs. in crores)	(Rs. in crores)
+465	77·00	45
+480	91·16	55
+490	1,01·00	62
+500	1,11·17	69
+510	1,23·00	77·5
+520	1,36·25	88
+530	1,56·00	1,01

The additional power potential afforded and the incremental cost of power between the diffcrent FRLs have then been evaluated and are given below :—

FRLs	Addl. power potential	Incremental cost	Cost /KW on incremental benefit
	MW at 60 per cent LF	(Rs. in crores)	
+465 to +480	60	10	1660
+480 to +490	47	7	1490
+490 to +500	68	7	1030
+500 to +510	55	8·5	1550
+510 to +520	67	10·5	1570
+520 to +530	65	13	2000

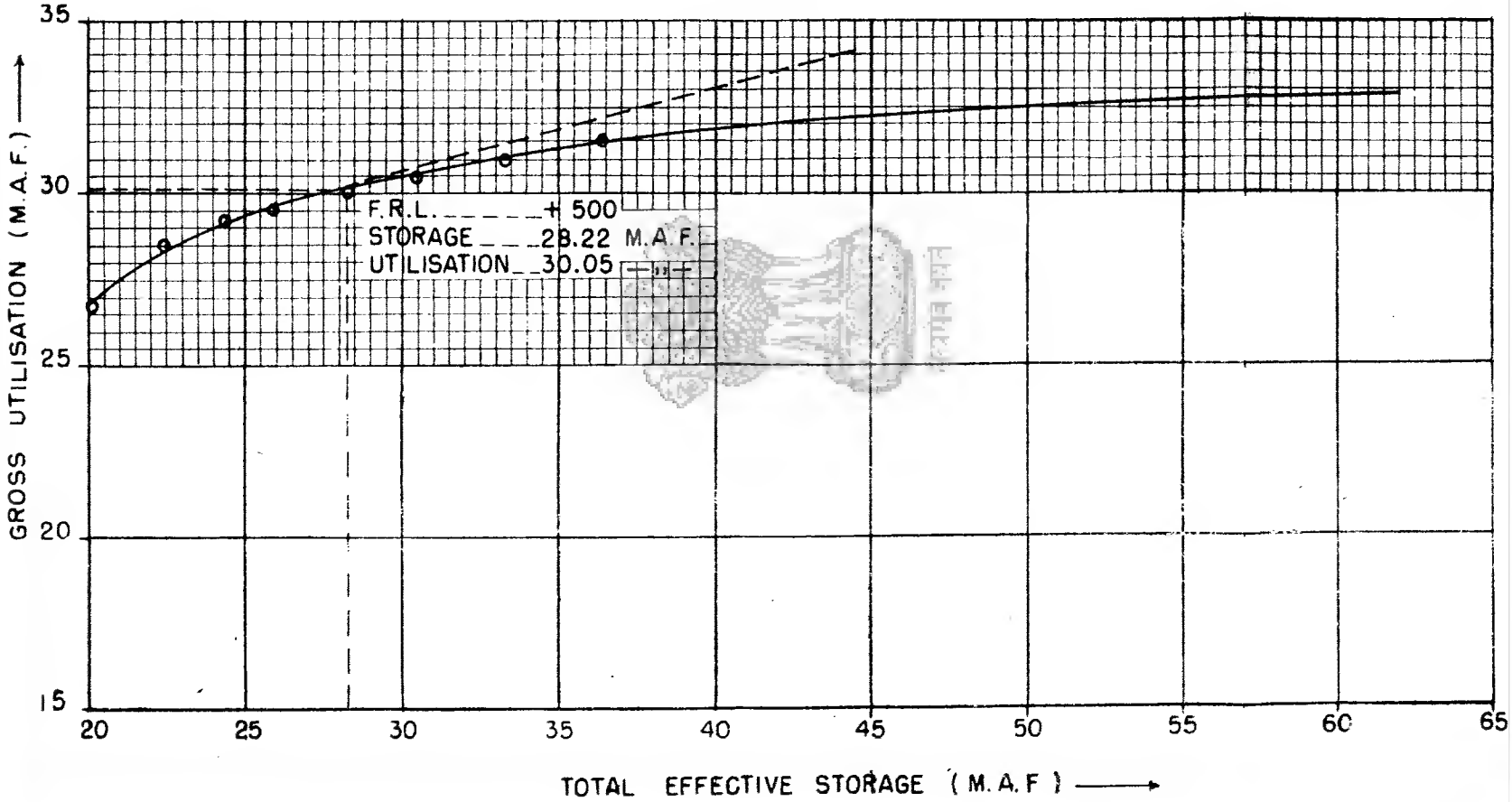
1·6 It is seen from above that the cost per KW on incremental benefit is lowest for FRL of Navagam dam +500, and increases considerably for FRL above +500. It can, therefore, be concluded that +500 is the optimum FRL to which Navagam dam can be raised.

PLATE XII-5

NARMADA VALLEY DEVELOPMENT

GROSS UTILISATION VS. TOTAL STORAGE

AT NAVAGAM



CHAPTER XIII

DISTRIBUTION OF COSTS AND BENEFITS

1·31 The Committee have recommended in Chapter XII that the best location for the terminal storage reservoir is at Navagam, thereby eliminating consideration of the dam sites at Jalsindhi and Hiranphal for the purpose. It is now necessary to study the cost aspects and then allocate the costs and benefits of this scheme among the States concerned.

All the upper developments on Narmada river lie in the State of Madhya Pradesh and their costs and benefits will go wholly to that State. It is only the terminal reservoir at Navagam which will be a common scheme among the three States of Madhya Pradesh, Maharashtra and Gujarat which are connected with the Narmada river. Some irrigation benefits will also be shared by Rajasthan with Gujarat, for which proportionate costs of the main canal and the Navagam dam will be contributed by the former according to the proportion of water allocated to it from the irrigation supplies.

Allocation between irrigation and power

1·32 The storage at Navagam will be used both for irrigation and power and the cost of the dam will, therefore, have to be allocated between these two aspects as the first step. This has been examined in detail and the calculations are given at Annexure XIII-1. It will be seen there from that for a total estimated cost of Rs. 111 crores for the Navagam Dam with FRL+500 (also MWL), the amounts chargeable to irrigation and power would be Rs. 42 crores and Rs. 69 crores, respectively.

The corresponding allocations between irrigation and power for FRLs+465, +480 and +490 have also been worked out in the same annexure for information.

Allocation of power benefits and costs between Madhya Pradesh, Maharashtra and Gujarat.

1·33 The cost of the power portion of the dam to be charged to each of the three States, viz., Madhya Pradesh, Maharashtra and Gujarat, will be in the ratio of the power benefits to be derived by them. The allocation of these benefits is discussed in the following paragraphs.

1·34 The high dam at Navagam (FRL+500) would involve considerable submergence in Madhya Pradesh, and although the cost of land compensation, etc., would be charged to the project, the burden of necessary administrative and other responsibilities involved in the rehabilitation of oustees would fall on that State. The magnitude of these problems will depend on the height of the dam finally adopted. Keeping this in view, the Committee feel that Madhya Pradesh should be given a relatively higher share in the allocation of power benefits arising at Navagam site.

1·35 Another point considered by the Committee was the allowance to be made in the share of Madhya Pradesh for the regulated releases from Punasa which would contribute to the power output at Navagam. In this connection it was felt that the regulated releases from the reservoirs above Punasa

would contribute substantially to the power generation at Punasa itself. Also, the releases from Punasa will be reused for power generation at Barwaha, which would be only a lift dam. Part of this water will also be used for irrigation. Madhya Pradesh would, thus, have derived significant benefits from the regulated releases passing below Punasa dam before they are used at Navagam dam.

1·36 A study of the benefits likely to accrue to Madhya Pradesh has been carried out for various stages of Narmada development and is given in Annexure XIII-2.

It will be noticed that according to this study, the share of the States in the power generation at Navagam (FRL+500) will be as under :—

Madhya Pradesh		Maharashtra		Gujarat
1·91	:	1	:	1

and for Navagam (FRL+465)

1·64	:	1		1

However, keeping in view the large-scale submergence in Madhya Pradesh and the consequent problem of rehabilitation to be faced by this State, the Committee feel that Madhya Pradesh should be given weightage in sharing the power benefits.

The Committee, therefore, propose the sharing of power benefits on the following basis :—

FRL at Navagam	Proposed sharing of power benefits at Navagam		
	Madhya Pradesh	Maharashtra	Gujarat
FRL			
+465	2·00	1	1
+480	2·15	1	1
+490	2·30	1	1
+500	2·50	1	1

The total power that will be generated at Navagam is given in Annexure XII-2 and the share proposed to be allocated to each State is indicated in Table 13·1.

TABLE 13·1

Sharing of Power at Navagam

For year 1985—the average year

FRL at Navagam	Total power generation at 60% LF (MW)	Share of each State in MW		
		Madhya Pradesh	Maharashtra	Gujarat
+465	776	388	194	194
+480	836	434	201	201
+490	883	473	205	205
+500	951	529	211	211

The share of cost to be borne by each State for, and the revenue earned from the power allotted as per Table 13.1 is shown in Annexure XIII-4A.

The relative power generated at Hiranphal and Navagam at various stages of development for FRLs+465 and +500 and the share of each State from Navagam power is indicated in the tables 13·2 and 13·3.

TABLE 13·2

Planwise share of Power from Navagam+500

	HIRANPHAL+500		NAVAGAM +500		Share of each State from Navagam +500					
					Madhya Pradesh		Maharashtra		Gujarat	
Year	Power at 60% L F. (MW)	Units generated Mil. Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.
1975	524	2750	1054*	7650	586	4250	234	1700	234	1700
1980	514	2700	1140†	6670	634	3710	253	1480	253	1480
1985	428	2250	951	5000	529	2780	211	1110	211	1110
1990	342	1800	696	3660	386	2040	155	810	155	810
1995	275	1450	511	2680	283	1480	114	600	114	600

*At the river bed power station, power at 60 per cent L. F. is restricted to 1000 MW only because of the installed capacity. Actually, 1000 MW will be available at 84 per cent L. F.

†At the river bed power station, power at 60 per cent L. F. is restricted to 1000 MW only because of the installed capacity. Actually, 1000 MW will be available at 68 per cent L. F.

TABLE 13·3

Planwise share of Power from Navagam + 465

Year	HIRANPHAL + 465		NAVAGAM + 465		Share of each State from Navagam + 465					
					Madhya Pradesh		Maharashtra		Gujarat	
	Power at 60% L.F. (MW)	Units generated Mil. Kwh.	Power at 60% (L.F. (MW)	Units generated Mil Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.	Power at 60% L.F. (MW)	Units generated Mil. Kwh.
1975	411	2160	1043*	6180	521	3080	261	1550	261	1550
1980	405	2130	1063	5600	531	2800	266	1400	266	1400
1985	330	1730	776	4080	338	2040	194	1020	194	1020
1990	256	1350	539	2830	269	1410	135	710	135	710
1995	199	1050	369	1940	185	960	92	490	92	490

*At the river bed power station, power at 60 per cent L. F. is restricted to 1000 MW only because of the installed capacity. Actually, 1000 MW willl be available at 68 per cent L. F.

The share of each State will be reduced proportionately if they decide by common agreement to supply some quantum of power from the common pool to Rajasthan. This subject is discussed in para. 13·9.

Navagam—Barwaha transmission link

13·7 The Committee further propose that the transmission link between Navagam and Barwaha with an intermediate grid sub-station at Hiranphal should be constructed as a common scheme between the three partner States and the share of Madhya Pradesh delivered at Hiranphal and Barwaha grid sub-stations through this link, the cost of which is estimated at about Rs. 12 crores. The Barwaha grid sub-station itself will be provided by Madhya Pradesh State at their own cost.

Allowance for regulated releases from Punasa

Regarding the question of allowance to be made in favour of Madhya Pradesh for the regulated releases from Punasa, mentioned in para. 13·5, the Committee feel that this cannot be accepted as a matter of principle, particularly in view of the significant benefits which Madhya Pradesh would have derived from these regulated releases before they reach Navagam. In the special circumstances of the case, however, the Committee would be agreeable to make some allowance for this also even though they have already allowed substantial weightage in power allocation in favour of Madhya Pradesh.

The amount of this allowance which may be considered appropriate has been worked out in Annexure XIII-3. According to that, the Committee feel that a fixed amount of Rs. 13 crores (irrespective of actual cost of the Punasa dam) be considered as a contribution of Madhya Pradesh to be adjusted against its share of cost of construction of Navgam dam, power plant and appurtenant works.

Of this Rs. 13 crores, Rs. 5 crores will be charged to irrigation and Rs. 8 crores to power.

Power to Rajasthan

13·8 In their note submitted to the Committee on the 17th December, 1964, the Rajasthan Government have stated that in a meeting held in June, 1962, the representatives of Madhya Pradesh and Gujarat had agreed to allot 50 MW of power to Rajasthan from the Narmada project. In view of acute shortage of power and lack of power resources in that State, they have approached the Committee for an allocation of 100 MW of power for their industrial development. While the Committee recognise the fact that Rajasthan cannot claim partnership in the power portion of the Narmada schemes, they support its claim for a reasonable allocation of power from the common pool of the Navagam project as a beneficiary. The quantum of power is left to the goodwill of the three partner States by common consent. A transmission link from Chambal project, which is a joint scheme of Rajasthan and Madhya Pradesh, already exists up to Indore, and it should be quite easy to extend this link up to Barwaha so as to connect the Chambal transmission system with Narmada system thereby facilitating exchange of an agreed quantum of power with Rajasthan.

Utilisation of Surplus Power

13 9 Since the rate of utilisation of the available power for each participating State may not necessarily proceed in proportion to its share in the total power generation, it will be necessary to make provision in the partnership agreement for temporary utilisation of the surplus power by the other partner States so that the overall benefits of the project are not lost. For this purpose an agreed grid-rate at the Navagam power house busbars will have to be worked out, allowing for a margin of up to 10 per cent over the estimated rate of generation. This rate will be applicable for sale of power from the share of any of the partners to the other partner States at high tension busbars of the step-up sub-station at Navagam power house. The partner States will, however, be free to sell this power at their normal bulk supply rates after transmission of power to their respective territories.

The Committee recommend that sale of such surplus power by any State should be made to other participating States in proportion to their shares specified in para. 13·7 limited to actual need if that be less than this apportionment.

13·10 One of the points raised by Madhya Pradesh during discussions was the relative cost at which power from Navagam would be made available to them at Hiranphal as compared to the cost of generation at Hiranphal itself.

The Committee have gone into this question very carefully and the relative capital costs per KW generated have been worked out in Annexure XIII-4B for a dam of FRL+500 and +465 at each place, i.e., Navagam and Hiranphal. The capital costs have been worked out on a uniform basis in both cases. This comparison clearly brings out the fact that the rates of power delivered at Hiranphal from Navagam will be more favourable compared to independent generation at Hiranphal.

13·11 Gujarat will be free to generate power on the canal and river system in the State at their own expense. The development of power at the head regulator of the canal will be in the common pool.

ANNEXURE XIII-1

SHARING OF COST OF NAVAGAM DAM BETWEEN IRRIGATION & POWER

Navagam FRL+500

In 1985, the year representing average benefits in the valley, the picture of water utilisation and power generation from the Navagam storage is expected to be as under—

(1) Water utilisation—

(*a*) For power generation at river bed power house	..	11·53 MAF
(*b*) For irrigation	..	8·40 MAF
Total	..	19·93 MAF

(2) Power generation at 60 per cent Load Factor—

(*a*) At river bed power house	..	725 MW
(*b*) At canal power house	..	135 MW
Total	..	860 MW

The waters let down for irrigation (8·4 MAF) will also be used for generating power at the canal power house.

The equivalent water required at the river bed power house to generate the same power as at the canal power house will be $11{\cdot}53 \times \frac{135}{725} = 2{\cdot}14$ MAF

Total water utilised for Power = 11·53 + 2·14 MAF = 13·67 MAF

Allocation of cost of dam between irrigation & power in the ratio of water utlised for the purpose, will thus be—

Irrigation	..	Power
8·40	:	13·67

Cost of Navagam dam (FRL+503) is estimated at Rs. 111·0 crores

$$\text{Cost chargeable to irrigation} = 111 \times \frac{8{\cdot}4}{22{\cdot}07} = 42{\cdot}2 \text{ Say Rs. 42 crores}$$

$$\text{Cost chargeable to power} = 111 \times \frac{13{\cdot}67}{22{\cdot}07} = 68{\cdot}8 \text{ Say Rs. 69 crores}$$

Navagam FRL+490

In 1985, the picture of water utilisation and power generation from the Navagam storage is expected to be as under—

(*i*) Water utilisation—

(*a*) For power generation at river bed P.H.		..	11·07 MAF
(*b*) For irrigation		..	8·40 MAF
	Total	..	19·47 MAF

(*ii*) Power generation at 60 per cent L. F.—

(*a*) At river bed P. H.		..	674 MW
(*b*) At canal P. H.		..	125 MW
	Total	..	799 MW

The equivalent water required at the river bed power house to generate the same power as at the canal power house will be $11{\cdot}07 \times \frac{125}{674} = 2{\cdot}08$ MAF

Total water utilised for power $= 11{\cdot}07 + 2{\cdot}08 = 13{\cdot}15$ MAF

Sharing the cost of the dam in the ratio of respective water utilisation

Irrigation	Power
8·40	13·15

For cost of Navagam dam (FRL+490) estimated at Rs. 101 crores

Cost chargeable to irrigation $= 101 \times \frac{8{\cdot}4}{21{\cdot}55} = 39{\cdot}4$, say Rs. 39 crores

Cost chargeable to power $= 101 \times \frac{13{\cdot}15}{21{\cdot}55} = 61{\cdot}6$, say Rs. 62 crores

Navagam FRL +480

In 1985, the picture of water utilisation and power generation from Navagam storage will be as under—

(1) Water utilisation—

(*a*) For power generation at river bed power house		..	10·77 MAF
(*b*) For irrigation		..	8·40 MAF
	Total	..	19·17 MAF

(2) Power generation at 60 per cent L. F.—

(*a*) At river bed power house	..	640 MW
(*b*) At canal power house	..	118 MW
Total	..	758 MW

The equivalent water required at the river bed power house to generate the same power as at canal power house $= 10{\cdot}77 \times \frac{118}{640} = 1{\cdot}99$ MAF

Total water utilised for power $= 10{\cdot}77 + 1{\cdot}99 = 12{\cdot}76$ MAF

Sharing the cost of Dam in the ratio of respective water utilisation—

Irrigation	:	Power
8·4		12·76

For estimated cost of Navagam dam (FRL+480) at Rs. 91·00 crores

Cost chargeable to irrigation $= 91{\cdot}00 \times \frac{8{\cdot}4}{21{\cdot}16}$ = Rs. 36 crores

Cost chargeable to power $= 91{\cdot}00 \times \frac{12{\cdot}76}{21{\cdot}16}$ = Rs. 55 crores

Navagam FRL+465

In 1985, the picture of water utilisation and power generation from the Navagam storage is expected to be as under—

(1) Water utilisation—

(*a*) For power generation at river bed power house	..	10·28 MAF
(*b*) For irrigation	..	8·40 MAF
Total	..	18·68 MAF

(2) Power generation at 60 per cent L. F.—

(*a*) At river bed power house	..	594 MW
(*b*) At canal power house	..	109 MW
Total	..	703 MW

The equivalent water required at the river bed power house to generate the same power as at the canal power house will be $10{\cdot}28 \times \frac{109}{594} = 1{\cdot}89$ MAF

Total water utilised for power generation $= 10{\cdot}28 + 1{\cdot}89 = 12{\cdot}17$ MAF

Sharing the cost of Dam in the ratio of respective water utilisation—

Irrigation	Power
8·4	12·17

For cost of Navagam dam (FRL+465) estimated at Rs. 77 crores

Cost chargeable to irrigation $= \frac{77 \times 8{\cdot}4}{20{\cdot}57} = 31{\cdot}5$, say Rs. 32 crores

Cost chargeable to power $= \frac{77 \times 12{\cdot}17}{20{\cdot}57} = 45{\cdot}5$, say Rs. 45 crores

The allocation of the cost of Navagam dam between irrigation & power for different full reservoir levels will thus be as under—

(Rs. in crores)

Sl. No.	FRL		* Total cost of dam	Cost chargeable to			
				Irrigation	Percentage	Power	Percentage
1	+500	..	111·0	42·0	37·8	69·0	62·2
2	+490	..	101·0	39·0	38·6	62·0	61·4
3	+480	..	91·0	36·0	39·6	55·0	60·4
4	+465	..	77·0	32·0	41·6	45·0	58·4

* As worked out and supplied by the C. W. & P. C.

ANNEXURE XIII-2

SHARING OF POWER BENEFITS FROM NAVAGAM+500

Irrigation development in the States of Madhya Pradesh and Maharastra & Gujarat and Rajasthan during the course of 30 years is presumed to be—

Development period from start of construction	Madhya Pradesh and Maharastra		Gujarat and Rajasthan	
	Area irrigated in lakh acres	Water requirement MAF	Area irrigated in lakh acres	Water requirement MAF
10 years ..	10·1	2·10	10·4	2·0
15 years ..	20·1	4·10	26	5·20
20 years ..	35·1	7·35	41	8·40
25 years ..	50·1	10·60	46·8	9·90
30 years ..	65·1	13·90	46·8	9·90

During the course of first ten years, dams at Navagam, Punasa, Bargi and Tawa are expected to be completed creating a total storage capacity of about 24·7 MAF. Some other developments are envisaged to take place and at the end of 15th year an additional storage capacity of about 3·5 MAF is assumed to have been created.

Navagam power (FRL+500)

With this storage capacity made available and the irrigation development as given above, total power generated at Navagam would be as given in the following table:—

Development period from start of construction (Years)	River bed power station				Canal power station			Total power at 60 per cent L. F. MW	Total units generated annually Million Kwh
	Potential power with available water at 60%LF	Installed capacity MW	Power at 100 per cent L. F. MW	Power at 60 per cent L. F. MW	Installed capacity MW	Power at 100 per cent L. F. MW	Power at 60 per cent L. F. MW		
10	1400	1100	840	1000*	120	32	54	1054	7650
15	1129	1100	678	1000*	240	84	140	1140	6670
20	725	1100	435	725	240	135	226	951	5000
25	430	1100	258	430	300	160	266	696	3660
30	245	1100	147	245	300	160	266	511	2680

* Power is restricted to 1000 MW only because of the installed capacity of 1100 MW with one unit of 100 MW as stand-by.

Hiranphal power (FRL+500)

If Hiranphal +500 is constructed in place of Navagam +500, assuming the same consumptive uses for irrigation in both cases, power generated at Hiranphal would be as follows :—

Development period	Power at 60 per cent L. F. MW
10 years	524
15 years	514
20 years	428
25 years	342
30 years	275

In order to determine the appropriate share of Madhya Pradesh in the power to be generated at Navagam, it will be fair to allocate to Madhya Pradesh the same quantum of power as it would have received from Hiranphal and allocate the balance power at Navagam to Maharashtra and Gujarat in equal proportions. Their respective shares will then be as per table below:—

Development period (years)	Total power at 60 per cent L.F. at Navagam MW	Hiranphal power as Madhya Pradesh share MW	Share of Maharashtra MW	Share of Gujarat MW	Ratio M. P./ (Gujarat+ Maharashtra)
10	1054	524	265	265	1·97:2·0
15	1140	514	313	313	1·65:2·0
20	951	428	261·5	261·5	1·65:2·0
25	696	342	177	177	1·95:2·0
30	511	275	118	118	2·33:2·0
Total average					9·55:10

Sharing of power generated at Navagam

Thus the sharing would be —

Madhya Pradesh	Maharashtra	Gujarat
1·91	1	1

The position for FRL +465 will be as follows :—

Development period (years)	Total power at Navagam 60 per cent LF MW	Hiranphal power as Madhya Pradesh share MW	Share of Maharashtra MW	Share of Gujarat MW	Ratio M. P/ (Gujarat+ Maharashtra)
10	1043	411	316	316	1·33:2·0
15	1063	405	329	329	1·23:2·0
20	776	330	223	223	1·48:2·0
25	539	256	141·5	141·5	1·81:2·0
30	369	199	85	85	2·34:2·0
Total average				..	8·19:10·0

Sharing of power generated at Navagam

Thus the sharing would be —

Madhya Pradesh		Maharashtra		Gujarat
1·64	:	1	:	1

ANNEXURE XIII-3

SHARING OF COST OF PUNASA DAM AMONG PUNASA, BARWAHA AND NAVAGAM PROJECTS

Allocation of cost of Punasa dam between irrigation and power

In 1985, the year representing the picture of average benefits in the valley, the water utilisation for irrigation and power from the Punasa storage is expected to be as under—

(*i*) For power generation	13·95 MAF
(*ii*) For irrigation (5 lakh acres at overall delta of 2·4 ft.).	1·20 MAF
Total	15·15 MAF

The cost of Punasa dam (FRL+860) is estimated at Rs. 40 crores. This may be shared between irrigation and power in the ratio of respective water utilisation i.e.

IRRIGATION	POWER
1·2	13·95

Cost chargeable to irrigation $= 40 \times \frac{1{\cdot}2}{15{\cdot}15} =$ Rs. 3·12 crores
Say Rs. 3 crores

Cost chargeable to power = Rs. 40—3 = Rs. 37 crores

Sharing of cost of power portion of Punasa dam among Punasa, Bharwaha and Navagam projects

Allowing a period of 10 years for the completion of the major reservoirs in the valley, the power releases at Punasa are likely to be of a high order for next 10 years or so, when irrigation would not have fully developed.

The maximum regulated release from Punasa is expected to be 16·3 MAF.

This would generate power of the order of 522 MW at 60 per cent L.F. at Punasa

At Barwaha, there will be no withdrawal for irrigation and the entire Punasa release will be utilised for power, generating 300 MW at 60 per cent L.F.

The power generation with this release at Navagam without any storage facilities with a head of 220 ft. (300—80) will be 584 MW at 60 per cent L.F.

Allocation of the cost of power portion of Punasa dam (Rs. 37 crores) in the ratio of the power generation at the three sites will be as under—

Punasa	Barwaha	Navagam
522 :	300 :	584

Cost chargeable to Punasa $= \frac{37 \times 522}{1406} =$ Rs. 13·8 crores

Cost chargeable to Barwaha $= \frac{37 \times 300}{1406} =$ Rs. 7·9 crores

Cost chargeable to Navagam $= \frac{37 \times 584}{1406} =$ Rs. 15·3 crores

Total .. Rs. 37·0 crores

With increased irrigation utilisation in Madhya Pradesh, the regulated release from Punasa will get reduced, thereby affecting the power generation at Barwaha and Navagam. It would not be reasonable to charge the lower projects towards the cost of Punasa dam on the basis of maximum release from Punasa.

The calculations for apportionment of the cost of the power portion of Punasa dam in the ratio of power generated with maximum release at Punasa and power generated at Barwaha and Navagam with minimum release are given below:—

The minimum release below Punasa has been worked out at 10·4 MAF at Barwaha and 7·4 MAF at Navagam. The power generation at 60 per cent L.F. at these two sites with the above release will be 192 MW and 270 MW, respectively.

The cost of power portion of the Punasa dam (Rs. 37 crores) will then be shared by the three projects as under—

Punasa		Barwaha		Navagam
522	:	192	:	270

Cost chargeable to Punasa $= \frac{37 \times 522}{984} =$ Rs. 19·6 crores

Cost chargeable to Barwaha $= \frac{37 \times 192}{984} =$ Rs. 7·3 crores

Cost chargeable to Navagam $= \frac{37 \times 270}{984} =$ Rs. 10·1 crores

The average cost chargeable to Navagam (for maximum and minimum release from Punasa) will thus be $\frac{15{\cdot}3 + 10{\cdot}1}{2} =$ Rs. 12·7, say Rs. 13 crores

This cost will be debitable to the irrigation and power portions of Navagam dam in the ratios indicated in the table at the end of Annexure XIII-1 for different FRLs of the dam. For Navagam (FRL+500) the amount chargeable to irrigation and power will be Rs. 5 crores and Rs. 8 crores, respectively.

ANNEXURE XIII-4-A

Share of cost of Navagam project to be borne by each State and revenue earned for power allotted

FOR THE YEAR 1985—THE AVERAGE YEAR

FRL at Navagam	Total power at 60% L. F. MW	Total cost of power portion Rs. crores	Madhya Pradesh			Maharashtra			Gujarat		
			Share Power MW	Share Cost Rs. Cr.	Revenue/ Yr. Rs. Cr.	Share Power MW	Share Cost Rs. Cr.	Revenue/ Yr. Rs. Cr.	Share Power MW	Share Cost Rs. Cr.	Revenue/ Yr. Rs. Cr.
+465 ..	776	119·0	388	59·5	6·10	194	29·75	3·04	194	29·75	3·04
+480 ..	836	132·3	434	68·5	6·85	201	31·9	3·16	201	31·9	3·16
+490 ..	883	140·5	473	75·3	7·60	205	32·6	3·24	205	32·6	3·24
+500 ..	951	147	529	81·6	8·33	211	32·7	3·33	211	32·7	3·33

NOTE : Revenue has been worked out at the average rate of 3 Paise per kwh sold in bulk

ANNEXURE

COMPARISON OF COST OF POWER GENERATION

(Assuming that the sum-at-charge does

Year			1975				1980			
			Power at 60 % L. F. MW	Units generated MKWH	Cost Per KW Rs.	Cost per KWH Paise	Power at 60 %L.F. MW	Units generated MKWH	Cost per KW Rs.	Cost per KWH Paise
		Rs. in crores								
Navagam +500.	*i.* Cost of Civil Works	,, 69 ,,								
	Cost of Elec. Inst.	,, 62 ,,								
		,, 131 ,,	1054*	7650	1,240	1·54	1140(a)	6670	1150	1·77
	ii. Adding Rs. 8 cr. for transmission & S/S.	,, 139 ,,	1054*	7650	1,320	1·63	1140(a)	6670	1,220	1·88
	iii. Adding Rs. 8 cr. for Punasa releases.	,, 147 ,,	1054*	7650	1,393	1·73	1140(a)	6670	1,290	1·98
Hiranphal +500.	*i.* Cost of Civil Works	,, 50 ,,								
	Cost of Elec. Inst.	,, 30 ,,	524	2750	1,530	2·62	514	2700	1,560	2·67
		,, 80 ,,								
	ii. Adding Rs. 8 cr for Punasa releases.	,, 88 ,,	524	2750	1,680	2·88	514	2700	1,720	2·93
Navagam +465.	*i.* Cost of Civil Works	,, 45 ,,								
	Cost of Elec. Inst.	,, 58 ,,	1043(a)	6180	988	1·50	1063	5600	968	1·65
		,, 103 ,,								
	ii. Adding Rs. 8 cr. for Transmission & S/S	,, 111 ,,	1043(a)	6180	1,062	1·62	1063	5600	1,043	1·78
	iii. Adding Rs. 8 cr. for Punasa releases.	,, 119 ,,	1043(a)	6180	1,140	1·73	1063	5600	1,120	1·91
Hiranphal +465.	*i.* Cost of Civil Works	,, 25 ,,								
	Cost of Elec. Inst.	,, 24 ,,	411	2160	1,192	2·04	405	2130	1,210	2·07
		,, 49								
	ii. Adding Rs. 8 cr. for Punasa releases.	,, 57 ,,	411	2160	1,390	2·37	405	2130	1,405	2·41

× From the year 1990 onwards Navagam Power Stations act as peaking stations

* At the river bed Power Station Power at 60 per cent L. F. is restricted to 1000 MW because of the installed

(a) At the river bed Power station at 60 per cent L. F. is restricted to 1000 MW because of the installed capacity

XIII-4 B-(1)

AT NAVAGAM AND HIRANPHAL

not set reduced below the capital costs

1985				1990×				1995×			
Power at 60 % L. F. MW	Units generated MKWH	Cost per KW Rs.	Cost per KWH paise	Power at 60 % L. F MW	Units gencrated MKWH	Cost per KW Rs.	Cost per KWH paise	Power at 60 % L. F. MW	Units generated MKWH	Cost per KW Rs.	Cost per KWH paise
951	5000	1,375	2·36	696	3660	1,885	3·22	511	268	2,570	4·40
951	5000	1,465	2·50	696	3660	2,000	3·42	511	268	2,720	4·68
951	5000	1,545	2·65	696	3660	2,110	3·61	511	268	2,880	4·93
428	2250	1,860	3·20	342	1800	2,340	4·0	275	1450	2,910	4·96
428	2250	2,050	3·52	342	1800	2,560	4·40	275	1450	3,200	5·47
776	4080	1,325	2·27	539	2830	1,910	3·28	369	1940	2,790	4·78
776	4080	1,430	2·45	539	2830	2,060	3·53	369	1940	3,000	5·15
776	4080	1,533	2·63	539	2830	2,210	3·78	369	1940	3,230	5·52
330	1730	1,482	2·55	256	1350	1,910	3·27	199	1050	2,460	4·20
330	1730	1,725	2·96	256	1350	2,226	3·80	199	1050	2,860	4·88

capacity of 1000 MW. Actually, 1000 MW will be available at 84 per cent L. F.

of 1000 MW. Actually, 1000 MW will be available at 68 per cent L. F.

ANNEXURE

COMPARISON OF COST OF POWER GENERATION

(Assuming that the sum at charge gets reduced by the surplus revenue after deducting interest and

Year		1975						1980					
Project		Power at 60 % L. F. (MW)	Sum at charge Rs. crores	Cost peKW (Rs)	× Units generated (MKWH)	Working expenses + Interest + (Rs. in crores).	Cost per KWH (Paise)	Power at 60 % L. F. (MW)	Sum at charge Rs. in crores	Cost per KW (Rs.)	× Units generated (MKWH)	Working expenses + Interest + (Rs. in crores).	Cost per KWH (Paise)
Navagam + 500	..	O 1054	1,45·9	1,380	7100	10·14	1·43	O 1140	89·5	800	6200	7·81	1·28
Hiranphal +500	..	524	* 88·0	1,680	2560	6·07	2·39	514	* 88·0	1,715	2510	6·07	2·42
Navagam + 465	..	O 1043	1,14·0	1,090	5750	8·21	1·43	1063	66·1	621	5200	6·04	1·16
Hiranphal +465	..	411	57·0	1,385	2010	3·93	1·95	405	50·2	1,240	1980	3·71	1·87

O Please see remarks under Annexure

* Where the sum at charge is more than

× Units generated exclude 7 per cent

+ This includes O/M charges and

XIII-4-B(2)

AT NAVAGAM AND HIRANPHAL

working expenses. (For figures under sum at charge please see attached statements of financial return)

1985						1990						1995					
Power at 60 % L. F. (MW)	Sum at charge Rs. crores	Cost per KW (Rs.)	× Units generated (MKWH)	Working expenses + Interest + (Rs. in crores).	Cost per KWH (Paise)	Power at 60 % L. F. (MW)	Sum at charge Rs. in crores	Cost per KW (Rs.)	× Units generated (MKWH)	Working expenses + Interest = (Rs. in crores).	Cost per KWH (Paise)	Power at 60 % L. F. (MW)	Sum at charge Rs. in crores	Cost per KW (Rs.)	× Units generated (MKWH)	Working expenses + Interest = (Rs. in crores).	Cost per KWH (Paise).
951	41·7	438	4650	5·31	1·14	696	3·56	51	3400	3·31	0·97	511	Nil	Nil	2500	2·97	1·19
428	88·0*	2,028	2090	6·07	2·90	342	88·0*	2,570	1670	6·07	3·63	275	8·80*	3,200	1340	6·07	4·53
776	23·96	308	3800	3·84	1·01	539	Nil	Nil	2640	2·26	0·86	369	Nil	Nil	1800	2·26	1·26
330	40·8	1,235	1610	3·21	2·00	256	34·8	1,360	1250	2·86	2·28	199	32·3	1,620	970	2·71	2·79

XIII-4-(B) (1)

the capital cost, the latter figure is adopted to work out the cost per KW.

towards line losses

depreciation at 1·9 per cent of capital cost and 5 per cent interest charges

STATEMENT OF FINANCIAL RETURN

NARMADA VALLEY DEVELOPMENT—NAVAGAM PROJECT (FRL+500)

		Rupees in crores
Cost of	power portion of Dam	.. 69
,,	Electrical installations	.. 62
,,	Transmission link to Hiranphal	.. 8
,,	Regulated releases from Punasa	.. 8
	Total Capital cost	.. 147

Interest at 5 per cent
O/M Charges at 1 per cent
Depreciation at 0·9 per cent
Average rate 3 Paise per KWH

Year	Capital to the commencement of the year.	Capital during the year	Interest at 5% of Col 2 and 2½% of Col. 3.	Depreciation at 0·9% of Col. 2	Load (MW) at 100%LF	Energy transmitted excluding 7% line losses (KWH) × 10⁹	Cost of generation, i.e., working expenses at 1% of Col. 2+ Col. 5.	Working expenses and Interest Col. 4+Col. 8.	Annual gross revenue at 3 Paise per unit.	Net revenue Col. 10—Col. 8	Surplus (+) or deficit (—) after meeting interest.	Accumulated surplus (+) or deficit(—).	Sum at charge at the end of the year.	Return Col. 11 as % of Col. 14.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores			Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	
1st Year ..	..	7·0	0·175	..	..	..	..	..	..	..	(—) 0·175	(—) 0·175	7·175	..
2nd Year ..	7·0	18·0	0·800	..	..	..	..	..	..	..	(—) 0·800	(—) 0·975	25·975	..
3rd Year ..	25·0	25·0	1·875	..	..	..	..	..	..	..	(—) 1·875	(—) 2·850	52·850	..
4th Year ..	50·0	33·0	3·325	..	..	..	..	..	..	..	(—) 3·325	(—) 6·175	89·175	..
5th Year ..	83·0	29·0	4·875	..	..	..	..	..	..	..	(—) 4·875	(—) 11·050	123·050	..
6th Year ..	112·0	18·0	6·050	1·008	156	1·27	2·128	8·178	3·81	1·682	(—) 4·368	(—) 15·418	145·418	1·15
7th Year ..	130·0	9·0	6·725	1·170	312	2·54	2·470	9·195	7·62	5·150	(—) 1·575	(—) 16·993	155·993	3·30
8th Year ..	139·0	5·0	7·075	1·251	468	3·81	2·641	9·716	11·43	8·789	(+) 1·714	(—) 15·279	159·279	5·52
9th Year ..	144·0	3·0	7·275	1·296	624	5·08	2·736	10·011	15·24	12·504	5·229	(—) 10·050	157·050	7·95

10th Year ..	147·0	..	7·350	1·323	872	7·10	2·793	10·143	21·30	18·507	11·157	(+)	1·107	145·893	12 65
11th Year ..	147·0	..	7·295	1·323	872	7·10	2·793	10·088	21·30	18·507	11·212		12·319	134·681	..
12th Year ..	147·0	..	6·679	1·323	872	7·10	2·793	9·472	21·30	18·507	11·828		24·147	122·853	..
13th Year ..	147·0	..	6·143	1·323	835	6·80	2·793	8·936	20·40	17·607	11·464		35·611	111·389	..
14th Year ..	147·0	..	5·569	1·323	798	6·50	2·793	8·362	19·50	16·707	11·138		46·749	100·251	..
15th Year ..	147·0	..	5·013	1·323	761	6·20	2·793	7·806	18·60	15·807	10·794		57·543	89·457	..
16th Year ..	147·0	..	4·473	1·323	723	5·89	2·793	7·266	17·67	14·877	10·404		67·947	69·053	..
17th Year ..	147·0	..	3·953	1·323	685	5·58	2·793	6·746	16·74	13·947	9·994		77·941	69·059	..
18th Year ..	147·0	..	3·453	1·323	647	5·27	2·793	6·246	15·81	13·017	9·564		87·505	59·495	..
19th Year ..	147·0	..	2·975	1·323	609	4·96	2·793	5·768	14·88	12·087	9·112		96·617	50·383	..
20th Year ..	147·0	..	2·519	1·323	571	4·65	2·793	5·312	13·95	11·157	8·638		105·255	41·745	..
21st Year ..	147·0	..	2·087	1·323	540	4·40	2·793	4·880	13·20	10·407	8·320		113·575	33·425	..
22nd Year..	147·0	..	1·671	1·323	510	4·16	2·793	4·464	12·48	9·687	8·016		121·591	25·409	..
23rd Year ..	147·0	..	1·270	1·323	480	3·91	2·793	4·063	11·73	8·937	7·667		129·258	17·742	..
24th Year ..	147·0	..	0·887	1·323	449	3·66	2·793	3·680	10·98	8·187	7·300		136·558	10·442	..
25th Year ..	147·0	..	0·522	1·323	418	3·40	2·793	3·315	10·20	7·407	6·885		143·443	3·557	..
26th Year ..	147·0	..	0·178	1·323	396	3·22	2·793	2·971	9·66	6·867	6·689		150·132	(—) 3·132	Against total investment of Rs. 147 crores.
27th Year ..	147·0	..	..	1·323	374	3·04	2·793	2·971	9·12	6·327	6·327		..	..	..
28th Year ..	147·0	..	..	1·323	352	2·87	2·793	2·971	8·61	5·817	5·817		..	..	..
29th Year ..	147·0	..	..	1·323	330	2·69	2·793	2·971	8·07	5·277	5·277		..	..	..
30th Year ..	147·0	..	..	1·323	307	2·50	2·793	2·971	7·50	4·707	4·707		..	..	..
31st Year ..	147·0	..	..	1·323	307	2·50	2·793	2·971	7·50	4·707	4·707		..	..	..

Note :—These financial statements are only illustrative. Each State Government will have to prepare its own financial statements on the basis of average unit rate at which power will be sold to consumers and in so doing the additional cost of transmission lines to the distribution centres for consumers will have to be added to the capital cost.

STATEMENT OF FINANCIAL RETURN

NARMADA VALLEY DEVELOPMENT—HIRANPHAL PROJECT (FRL+500)

Cost of Dam .. 50
Cost of Electrical installation .. 30
„ Regulated releases from Punasa .. 8

Total capital cost Rs. 88 crores

Interest at .. 5 per cent
O/M. charges .. 1 per cent
Depreciation at .. 0·9 per cent

Average rate .. 3 Paise per KWH

Year	Capital to the commencement of the year.	Capital during the year	Interest at 5 per cent of Col. 2 and 2½% of Col. 3.	Depreciation at 0·9 per cent of Col. 2	Load (MW) at 100 per cent LF	Energy transmitted excluding 7 per cent line losses (KWH) × 10⁹	Cost of generation, i.e., working expenses at 1 per cent of Col. 2+Col. 5.	Working expenses and Interest Col. 4+Col. 8.	Annual gross revenue at 3 Paise per unit.	Net revenue Col. 10— Col. 8	Surplus (+) or deficit (—) after meeting interest.	Accumulated surplus (+) or deficit (—).	Sum at charge at the end of the year.	Return Col. 11 as % of Col. 14.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Rupees crores									Rupees crores				
1st year ..	..	5·00	0·125	..	..	..	..	..	..	..	(—)0·125	(—) 0·125	5·125	..
2nd year ..	5·00	11·00	0·525	..	..	..	..	..	..	..	(—)0·525	(—) 0·650	16·650	..
3rd year ..	16·00	14·00	1·150	..	..	..	..	..	..	..	(—)1·150	(—) 1·800	31·800	..
4th year ..	30·00	20·00	2·000	..	..	..	..	..	..		(—)2·000	(—) 3·800	53·800	..
5th year ..	50·00	13·00	2·825	..	..	..	..	..	..	..	(—)2·825	(—) 6·625	69·625	..
6th year ..	63·00	10·00	3·400	0·567	60	0·49	1·197	4·597	1·47	0·273	(—)3·127	(—) 9·752	82·752	0·33
7th year ..	73·00	7·00	3·825	0·657	120	0·98	1·387	5·212	2·94	1·553	(—)2·272	(—)12·024	92·024	1·69
8th year ..	80·00	5·00	4·125	0·720	180	1·47	1·520	5·645	4·41	2·890	(—)1·235	(—)13·259	98·259	2·94
9th year ..	85·00	3·00	4·325	0·765	240	1·96	1·615	5·940	5·88	4·265	(—)0·060	(—)13·319	101·319	4.22

[illegible]	88·00	..	4·400	0·792	314	2·56	1·672	6·072	7·68	6·008	(+)1·608	(—)11·711	99·711	6·01
11th year ..	88·00	..	4·400	0·792	314	2·56	1·672	6·072	7·68	6·008	1·608	(—)10·103	98·103	6·10
12th year ..	88·00	..	4·400	0·792	314	2·56	1·672	6·072	7·68	6·008	1·608	(—) 8·495	96·495	6·20
13th year ..	88·00	..	4·400	0·792	310	2·52	1·672	6·072	7·56	5·888	1·488	(—) 7·007	95·007	6·20
14th year ..	88·00	..	4·400	0·792	310	2·52	1·672	6·072	7·56	5·888	1·488	(—) 5·519	93·519	6·29
15th year ..	88·00	..	4·400	0·792	308	2·51	1·672	6·072	7·53	5·858	1·458	(—) 4·061	92·061	6·38
16th year ..	88·00	..	4·400	0·792	298	2·42	1·672	6·072	7·26	5·588	1·188	(—) 2·873	90·873	6·15
17th year ..	88·00	..	4·400	0·792	288	2·34	1·672	6·072	7·02	5·348	0·948	(—) 1·925	89·925	5·95
18th year ..	88·00	..	4·400	0·792	278	2·26	1·672	6·072	6·78	5·108	0·708	(—) 1·217	89·217	5·73
19th year ..	88·00	..	4·400	0·792	268	2·18	1·672	6·072	6·54	4·868	0·468	(—) 0·749	88·749	5·62
20th year ..	88·00	..	4·400	0·792	257	2·09	1·672	6·072	6·27	4·598	0·198	(—) 0·551	88·551	5·20
21st year ..	88·00	..	4·400	0·792	247	2·01	1·672	6·072	6·03	4·358	(—)0·042	From this stage, annual working expenses+interest on capital exceed the annual gross revenue.		
22nd year ..	88·00	..	..	0·792	237	1·93	1·672	..	5·79	4·118	..			
23rd year ..	88·00	..	..	0·792	227	1·85	1·672	..	5·55	3·878				
24th year ..	88·00	..	..	0·792	217	1·77	1·672	..	5·31	3·638				
25th year ..	88·00	..	..	0·792	205	1·67	1·672	..	5·01	3·338				
26th year ..	88·00	..	..	0·792	197	1·61	1·672	..	4·83	3·158				
27th year ..	88·00	..	..	0·792	189	1·54	1·672	..	4·62	2·948				
28th year ..	88·00	..	..	0·792	181	1·47	1·672	..	4·41	2·738				
29th year ..	88·00	..	..	0·792	173	1·41	1·672	..	4·23	2·558				
30th year ..	88·00	..	..	0·792	165	1·34	1·672	..	4·02	2·348				
31st year ..	88·00	..	..	0·792	165	1·34	1·672	..	4·02	2·348				

STATEMENT OF FINANCIAL RETURN

NARMADA VALLEY DEVELOPMENT—NAVAGAM PROJECT (FRL+465)

		Rupees crores
Cost of	Power portion of dam ..	45
,,	Electrical installations ..	58
,,	Transmission link to Hiranphal ..	8
,,	Regulated releases from Punasa ..	8
	Total Capital cost ..	119

Interest at 5%
O/M charges at 1%
Depreciation at 0·9 %
Average rate 3 Paise per KWH

Year	Capital to the commencement of the year.	Capital during the year	Interest at 5% of Col 2 and 2½% of Col. 3.	Depreciation at 0·9% of Col. 2.	Load (MW) at 100% L.F.	Energy transmitted excluding 7% line losses (KWH)×10⁹	Cost of generation, i.e., working expenses at 1% of Col. 2+ Col. 5.	Working expenses and Interest Col. 4+Col. 8.	Annual gross revenue at 3 Paise per unit.	Net revenue Col. 10— Col. 8	Surplus (+) or deficit (—) after meeting interest.	Accumulated surplus (+) or deficit(—).	Sum at charge at the end of the year.	Return Col. 11 as % of Col. 14.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores			Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	
1st year	..	6·0	0·150	..	..	..	..	..	..	..	(—) 0·150	(—) 0·150	6·150	..
2nd year	6·0	14·0	0·650	..	..	..	..	..	..	..	(—) 0·650	(—) 0·800	20·800	..
3rd year	20·0	20·0	1·500	..	..	..	..	..	..	..	(—) 1·500	(—) 2·300	42·300	..
4th year	40·0	26·0	2·650	..	..	..	..	..	..	..	(—) 2·650	(—) 4·950	70·950	..
5th year	66·0	21·0	3·825	..	..	..	..	..	..	..	(—) 3·825	(—) 8·775	95·775	..
6th year	87·0	15·0	4·725	0·783	140	1·14	1·653	6·378	3·42	1·767	(—) 2·958	(—) 11·733	113·733	1·55
7th year	102·0	9·0	5·325	0·918	280	2·28	1·938	7·263	6·84	4·902	(—) 0·423	(—) 12·156	123·156	3·98

8th year	111·0	5·0	5·675	0·999	420	3·42	2·109	7·784	10·26	8·151	(+)2·476	(—)9·680	125·680	6·50
9th year	116·0	3·0	5·875	1·044	560	4·56	2·204	8·079	13·68	11·476	(+)5·601	(—)4·079	123·079	8·50
10th year	119·0	..	5·950	1·071	705	5·75	2·261	8·211	17·25	14·989	9·039	(+)4·960	114·040	13·14
11th year	119·0	..	5·702	1·071	705	5·75	2·261	7·963	17.25	14·989	9·287	14·247	104·753	..
12th year	119·0	..	5·238	1·071	705	5·75	2·261	7·499	17·25	14·989	9·751	23·998	95·002	..
13th year	119·0	..	4·750	1·071	683	5·57	2·261	7·011	16·71	14·449	9·699	33·697	85·303	..
14th year	119·0	..	4·265	1·071	661	5·40	2·261	6·526	16·20	13·939	9·674	43·371	75·629	..
15th year	119·0	..	3·781	1·071	638	5·20	2·261	6·042	15·60	13·339	9·558	52·929	66·071	..
16th year	119·0	..	3·304	1·071	604	4·92	2·261	5·565	14·76	12·499	9·195	62·124	56·876	..
17th year	119·0	..	2·844	1·071	570	4·65	2·261	5·105	13·95	11·689	8·845	70·969	48·031	..
18th year	119·0	..	2·402	1·071	536	4·37	2·261	4·663	13·11	10·849	8·447	79·416	39·584	..
19th year	119·0	..	1·979	1·071	502	4·10	2·261	4·240	12·30	10·039	8·060	87·476	31·524	..
20th year	119·0	..	1·576	1·071	466	3·80	2·261	3·837	11·40	9·139	7·563	95·039	23·961	..
21st year	119·0	..	1·198	1·071	438	3·57	2·261	3·459	10·71	8·449	7·251	102·290	16·710	..
22nd year	119·0	..	0·836	1·071	410	3·34	2·261	3·097	10·02	7·759	6 923	109·213	9·787	..
23rd year	119·0	..	0 489	1·071	382	3·12	2·261	2·750	9·36	7·099	6·610	115·823	3·177	..
24th year	119·0	..	0·159	1·071	354	2·89	2·261	2·420	8·67	6·409	6·250	122·073	(—)3·073	Against total investment of Rs. 119 crores.
25th year	119·0	..	..	1·071	323	2·64	2·261	2·261	7·92	5·659	5·659	..	..	
26th year	119·0	..	..	1·071	303	2·47	2·261	2·261	7·41	5·149	5·149	..	..	..
27th year	119·0	..	..	1·071	283	2·31	2·261	2·261	6·93	4·669	4·669	..	..	..
28th year	119·0	..	..	1·071	263	2·14	2·261	2·261	6·42	4·159	4·159	..	..	..
29th year	119·0		..	1·071	243	1·98	2·261	2·261	5·94	3·679	3·679	..	..	..
30th year	119·0	..	..	1·071	221	1·80	2·261	2·261	5·40	3·139	3·139	..	..	..
31st year	119·0	..	..	1·071	221	1·80	2·261	2·261	5·40	3·139	3·139	..	..	..

NOTE—These financial statements are only illustrative. Each State Government will have to prepare its own financial statements on the basis of average unit rate at which power will be sold to consumers and in so doing the additional cost of transmission lines to the distribution centres for consumers will have to be added to the capital cost.

STATEMENT OF FINANCIAL RETURN

NARMADA VALLEY DEVELOPMENT—HIRANPHAL PROJECT (FRL+465)

	Rupees in crores
Cost of Dam	.. 25
,, Electrical installations	.. 24
,, Regulated releases from Punasa	.. 8
,, Total Capital cost	.. 57

Interest at 5 per cent
O/M charges 1 per cent
Depreciation at 0·9 per cent
Average rate 3 Paise per KWH

Year	Capital to the commencement of the year.	Capital during the year	Interest at 5% of Col. 2 and 4% of Col. 3.	Depreciation at 0·9% of Col. 2.	Load (MW) at 100%LF	Energy transmitted excluding 7% line losses(KWH)×10⁶	Cost of generation, i.e., working expenses at 1% of Col. 2+ Col. 5.	Working expenses and Interest Col. 4+Col. 8.	Annual gross revenue at 3 Paise per unit.	Net revenue Col. 10—Col. 8	Surplus (+) or deficit (—) after meeting interest.	Accumulated surplus (+) or deficit(—).	Sum at charge at the end of the year.	Return Col. 11 as % of Col. 14.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores	Rs. Crores
1st year	3·00	3·00	0·075	..	..	..	..	..	..	..	(—)0·075	(—)0·075	3·075	..
2nd year	3·00	6·00	0·300	..	..	..	..	..	..	..	(—)0·300	(—)0·375	9·375	..
3rd year	9·00	9·00	0·675	..	..	..	..	..	..	..	(—)0·675	(—)1·050	19·050	..
4th year	18·00	11·00	1·175	..	..	..	..	..	..	..	(—)1·175	(—)2·225	31·225	..
5th year	29·00	8·00	1·650	..	..	..	..	..	..	..	(—)1·650	(—)3·875	40·875	..
6th year	37·00	6·00	2·000	0·333	45	0·37	0·703	2·703	1·11	0·407	(—)1·593	(—)5·468	48·468	0·86
7th year	43·00	6·00	2·300	0·387	90	0·74	0·187	3·117	2·22	1·403	(—)0·897	(—)6·365	55·365	2·52
8th year	49·00	5·00	2·575	0·441	135	1·10	0·931	3·506	3·30	2·369	(—)0·206	(—)6·571	60·571	3·91

9th year	54·00	3·00	2·775	0·486	180	1·47	1·026	3·801	4·41	3·384	(+)0·609	(—)5·962	62·962	5·36
10th year	57·00	..	2·850	0·513	247	2·01	1·083	3·935	6·03	4·947	2·097	(—)3·865	60·865	8·12
11th year	57·00	..	2·850	0·513	247	2·01	1·083	3·933	6·03	4·947	2·097	(—)1·768	58·768	8·42
12th year	57·00	..	2·850	0·513	247	2·01	1·083	3·933	6·03	4·947	2·097	(+)0·329	56·671	8·74
13th year	57·00	..	2·834	0·513	245	1·99	1·083	3·917	5·97	4·887	2·053	2·382	54·618	8·95
14th year	57·00	..	2·731	0·513	245	1·99	1·083	3·814	5·97	4·887	2·156	4·538	52·462	9·55
15th year	57·00	..	2·623	0·513	243	1·98	1·083	3·706	5·94	4·857	2·234	6·772	50·228	9·68
16th year	57·00	..	2·511	0·513	234	1·90	1·083	3·594	5·70	4·617	2·106	8·878	48·122	9·57
17th year	57·00	..	2·406	0·513	225	1·83	1·083	3·489	5·49	4·407	2·001	10·879	46·121	9·56
18th year	57·00	..	2·306	0·513	216	1·76	1·083	3·389	5·28	4·197	1·891	12·770	44·230	9·50
19th year	57·00	..	2·211	0·513	207	1·69	1·083	3·294	5·07	3·987	1·776	14·546	42·454	9·40
20th year	57·00	..	2·123	0·513	198	1·61	1·083	3·206	4·83	3·747	1·624	16·170	40·830	9·20
21st year	57·00	..	2·041	0·513	190	1·55	1·083	3·124	4·65	3·567	1·526	17·696	39·304	9·10
22nd year	57·00	..	1·965	0·513	181	1·47	1·083	3·048	4·41	3·327	1·362	19·058	37·942	8·80
23rd year	57·00	..	1·897	0·513	172	1·40	1·083	2·980	4·20	3·117	1·220	20·278	36·722	8·50
24th year	57·00	..	1·836	0·513	163	1·33	1·083	2·919	3·99	2·907	1·071	21·349	35·651	8·19
25th year	57·00	..	1·782	0·513	154	1·25	1·083	2·865	3·75	2·667	0·885	22·234	34·766	7·68
26th year	57·00	..	1·738	0·513	147	1·20	1·083	2·821	3·60	2·517	0·779	23·013	33·987	7·32
27th year	57·00	..	1·699	0·513	140	1·14	1·083	2·782	3·42	2·337	0·638	23·651	33·349	7·01
28th year	57·00	..	1·667	0·513	133	1·08	1·083	2·750	3·24	2·157	0·490	24·141	32·859	6·57
29th year	57·00	..	1·643	0·513	126	1·02	1·083	2·726	3·06	1·977	0·334	24·475	32·525	6·10
30th year	57·00	..	1·626	0·513	119	0·97	1·083	2·709	2·91	1·827	0·201	24·676	32·324	5·65
31st year	57·00	..	1·616	0·513	119	0·97	1·083	2·699	2·91	1·827	0·211	24·887	32·113	5·70

CHAPTER

COMMITTEE'S MASTER PLAN FOR OPTIMUM AND INTEGRA

14·1 The Master Plan for the full utilisation of irrigation and power benefits major projects given in Table 14·1 (shown in Plate XIV-1) besides a large number of

TABLE

Master Plan for the optimum and

Sl. No.	Name of the Project	Catchment area (sq. miles)	Area submerged (acres)	Mean annual rainfall (inches)	Mean annual runoff (MAF)	Storage		Mean regulated flow			Area	
						Gross	Live (MAF)	Total	For irrigation (cusecs)	For Power	Kharif	Rabi (thousand
1.	Rosra ..	1,800	25,000	60·0	2·44	2·10	1·95	2,180	..	2,180	..	..
2.	Basania ..	3,700	10,500	62·0	5·02	Lift Dam		4,200	..	4,200	..	..
3.	Burhner ..	1,272	24,000	60·0	1·73	1·75	1·56	1,700	..	1,700	..	..
4.	Bargi ..	5,620	70,300	60·0	7·63	3·40	2·80	5,450	..	5,450	117	378
5.	Chinki ..	9,150	13,500	54·0	11·75	Lift Dam		5,130	..	5,130	..	..
6.	Sitarewa ..	77	2,600	55·0	0·15	0·10	0·08	166	..	166	..	..
7.	Barna ..	454	17,500	44·0	0·49	0·40	0·33	356	356	..	26	129
8.	Hoshangabad	14,550	65,000	53·0	18·04	Lift Dam		5,250	..	5,250	..	..
9.	Tawa ..	2,310	68,200	59·0	3·65	2·95	2·26	2,400	1,550	2,400(*a*)	262	450
10.	Kolar ..	196	4,700	46·0	0·28	0·17	0·15	235	235	..	31	89
11.	Punasa ..	23,800	2,25,000	51·0	28·83	9·90	8·40	20,910	1,660	19,250	325	150
12.	Barwaha ..	25,050	27,000	51·0	31·17	Lift Dam		19,250	1,250	18,000	130	60
13.	Navagam ..	33,790	2,18,500	48·0	35·94	14·40	11·20	27,500	11,590	15,910	2,580	1,120
	Total ..	..	7,71,800	..	..	35·17	28·73	..	..	..	3,471	2,376

(*a*) Including irrigation withdrawal

XIV

TED DEVELOPMENT OF NARMADA WATER RESOURCES

from the waters of Narmada river as envisaged by the Committee will cover the medium and minor irrigation projects in Madhya Pradesh.

14·1

integrated development of the Narmada water resources

(20 years after start of construction)

irrigated annually		Power generation				Irrigation in ultimate stage				Cost of Project		
Perennial acres)	Total	Average head (ft.)	100 per cent L.F. (MW)	60 per cent L.F. (MW)	Units generated (Million Kwh)	Kharif (thousand	Rabi acres)	Perennial	Total	Irriga-tion (rupees	Power in crores)	Total
..	..	200	31	52	273	..	..	..	..	..	25·0	25·0
..	..	120	36	60	315	..	..	..	..	..	16·0	16·0
..	..	140	17	28	149	..	..	..	..	..	19·0	19·0
37	532	154	60	100	526	117	378	37	532	26·0	25·0	51·0
..	..	90	33	55	289	..	..	..	..	..	17·0	17·0
..	..	650	7	11	59	..	..	..	..	..	2·0	2·0
9	164	..	..	..	..	26	129	9	164	6·0	..	6·0
..	..	80	30	50	263	..	..	..	..	..	17·0	17·0
38	750	70	12	20	105	262	450	38	750	20·0	8·0	28·0
3	123	..	..	..	..	31	89	3	123	5·0	..	5·0
25	500	193	268	446	2,348	390	180	30	600	33·0	57·0	90·0
10	200	115	145	241	1,270	195	90	15	300	17·0	23·0	40·0
140	3,840	River bed 385 Canal 165	692	1,153	6.062	3,142	1,362	176	4,680	276·0	139·0	415·0
262	6,109	..	1,331	2,216	11,659	4,163	2,678	308	7,149	383·0	348·0	731·0
Medium and minor irrigation works in Madhya Pradesh, lift dams for power between Bargi-Hoshangabad and Hoshangabad-Punasa, and irrigation in Maharashtra.									4,041		259·0	
Navigation structures and ancillary works									..		60·0	
									Grand Total ..		Rs. 1,050·0	crores

As already mentioned in Chapter IV, a few of these projects have been investigated in any detail and most of them have not been investigated at all. Also, the other relevant data available are in many cases a matter of guess. Subject to these limitations, an attempt has been made to draw up a Master Plan in broad outline which indicates, approximately, the irrigation and power potential of the Niarmada basin and the relevant costs as best as can be estimated under these circumstances.

Use has been made of the project reports prepared by the Central Water and Power Commission and all other data and information available with them. The services of the C. W. & P. C. have been freely drawn upon, as necessary.

Full use has also been made of the documents presented to the Committee from time to time by the various State Governments.

14·2 In drawing up the phased programme of basin-wide development, the Committee had the following basic considerations in view;

firstly, the acute shortage of food and the imperative need for accelerated pace of irrigation development to provide more food ;

secondly, the all-round power shortage which is hampering the progress of industries as well as rural development, including rural industries and pumping for irrigation ;

thirdly, the necessity for raising financial resources, possible mainly through power development, for investment in other essential projects ; and

fourthly, the reported decision of the Planning Commission to make massive allocation for irrigation and power during the Fifth, Sixth and subsequent Plans.

14·3 The Committee is conscious of the fact that irrigation projects, though absolutely essential for more food production, are financially unproductive and, presently, a burden on the State exchequer. On the other hand power projects are productive, providing resources which would meet the deficit of irrigation projects and still leave margin for investment in other projects of development.

14·4 Based on the above considerations, the Committee have envisaged a rate of irrigation development much in excess of what is justified by current performance. On the other hand, the development of hydro power has been envisaged to the ultimate generation capacity simultaneously with the construction of dams, on the understanding that, according to the load forecasts presented by the three States concerned (Table 14·2), the power will be used up as fast as it is generated.

TABLE 14·2

LOAD FORECASTS OF MADHYA PRADESH, MAHARASHTRA AND GUJARAT

Year	Madhya Pradesh MW	Maharashtra MW	Gujarat MW
1967-68	N.A.	1604	571
1970-71	1500	2288	1050
1975-76	N.A.	3677	1960
1980-81	N.A.	5517	2940

Phasing of major projects

First phase of development

14·5 The Committee accordingly recommend expediting the projects already sanctioned, namely, the Tawa and Barna and taking up Punasa and Bargi in Madhya Pradesh; and Navagam in Gujarat.

TAWA AND BARNA PROJECTS

14·6 The Tawa and Barna projects which were sanctioned under the Second Five Year Plan, and work on which is in hand, should be expedited with a view to early completion, so that their benefits may be available at an early date and the rehabilitation of displaced persons from East Pakistan, who have been sent there, may be facilitated.

PUNASA PROJECT

14·7 It is obvious that the Punasa dam project is a key project in the development of the Narmada basin. Besides generating a large block of power, it would give a regulated supply throughout the year for generation of power and development of irrigation in the lower reach. Investigations of the project have already been carried out by the Central Water and Power Commission and a project report establishing the feasibility of the dam has been prepared.

Considerable amount of work of drilling, drifts, etc., at site is, however, necessary for the preparation of the detailed project estimates. This should be undertaken immediately as an essential preliminary. While this exploratory work is in progress, the construction of other essential preliminaries like roads, buildings, water-supply arrangements, power, collection of materials and machinery should proceed simultaneously so that actual work of the dam construction in the river bed may be taken up without delay.

The construction of canals for irrigation of such areas as Madhya Pradesh wish to command from Punasa dam should also be taken in hand along with the dam so that they may be ready to use water as soon as it becomes available.

BARGI PROJECT

14·8 The Bargi dam is another important project which should be started along with Punasa. Madhya Pradesh in their Master Plan have proposed that Bargi should be only a power dam in the first instance. The Committee, however,

feel that the canal system must have precedence over power development because power in large quantity will be available from other projects whereas for the resettlement of the population displaced by the Punasa, Navagam and Bargi reservoirs, large areas with irrigation facilities will be urgently needed. At the meeting in 1961, in the room of Member (D & R), Central Water and Power Commission, the Madhya Pradesh representative stressed the irrigation aspect of Bargi project and asked for the entire project, including irrigation, to be proceeded with. The Committee are in agreement with this view.

MEDIUM AND MINOR IRRIGATION PROJECTS

14.9 Madhya Pradesh intend to irrigate very large areas from medium and minor works on the tributary streams of the main river. They may proceed with this work to the extent resources in staff, funds and material permit after meeting the demands of the major projects listed above.

NAVAGAM PROJECT

14·10 In Gujarat, the work on the essential preliminaries for the high Navagam dam with FRL+500, such as construction of access roads, residential and office buildings, workshops, power supply, essential stores, should also be started forthwith and the project should form part of the first stage development of the Narmada basin. The investigations of foundation conditions, geology, materials, etc., on this project are in an advanced stage. The main access road, some buildings and labour camps have already been constructed. The work of construction of the main dam in the river bed can, therefore, be taken up at a relatively earlier date.

NAVAGAM CANAL

14·11 The canal system from Navagam, which is a long and difficult one, will also have to be started at an early date to enable Gujarat to take full advantage of the larger supplies (particularly for purposes of reclamation of saline lands), which would be available in the Narmada in earlier years while irrigation in Madhya Pradesh is still developing. To ensure this, the three stage construction visualised by Gujarat for this canal should be taken up in one stage as a whole. It has to be remembered that the saline areas and the Rann of Kutch lie at the tail-end of the system, and if there is any delay in getting water to these places, the chance of using additional water for reclamation and land improvement in the earlier years, when larger surpluses would be available, will be lost.

The early completion of this canal is also necessary to carry irrigation water to the Great Rann of Kutch and Rajasthan deserts and both of which have a common border with Pakistan.

LAND ACQUISITION, RESETTLEMENT AND REHABILITATION

14·12 According to the Madhya Pradesh Master Plan (Page 19, volume II), the area to be submerged by the various major irrigation and power projects on the Narmada and its tributaries will be nearly 6·82 lakh acres. Under the integrated plan of development envisaged by the Committee, about 8 lakh acres will have to be acquired over a period of about 20 years. In addition, about 16 lakh acres may have to be acquired in due course for medium and minor irrigation projects in Madhya Pradesh.

14·13 The resettlement and rehabilitation of persons displaced as a result of the construction of these projects will present a major human problem, particularly in the case of the major reservoirs included in the first phase, namely, Punasa, Bargi, Tawa, Barna and Navagam, which together will submerge an area of six lakh acres.

14·14 As most of the displaced persons will be agriculturists, it would be necessary to find alternative lands for their resettlement. Normally, an agriculturist, particularly a small owner, should get land for land. Cash compensation to a poor land-holder will be a temptation to his creditor or the money-lender and will soon pass on to them, leaving the cultivator a landless and destitute labourer.

14·15 Whatever lands are selected and reclaimed for resettlement should have adequate irrigation facilities to ensure good crops. Without irrigation, reclaimed lands will not attract settlers. It is for this reason that the Committee have suggested the inclusion of the Bargi project in the first phase so that large irrigated areas, of which a substantial part may be Government lands, become available for resettlement of the oustees.

14.16 The best solution would, however, be to reclaim waste lands, which will presumably be mostly Government lands, on the fringes of the reservoirs and provide them with perennial irrigation from medium and minor works constructed on the minor streams or from the reservoirs. This will have the added advantage of the oustees being resettled close to their original habitation.

14·17 The time factor is of prime importance in the resettlement of oustees. The land on which they are to be resettled should be selected, made ready and allotted well, say 6 to 12 months, before their original lands are submerged. If there is a time lag between the submergence of the original land and allotment of new land, and payments have to be made in cash, the small landholder is likely to spend the money before new land is allotted to him, leaving him destitute. Advance planning is, therefore, necessary in this direction. The planning and implementation of land reclamation and resettlement programmes, including provision of irrigation facilities, should be undertaken simultaneously with the planning and execution of the storage projects. Special attention should be given to prompt payment of compensation and to have reclaimed lands and housing ready in advance of actual dates of submergence so that the transfer from the old place to new ones be smooth and orderly and human suffering caused by delays of formalities avoided.

As a rule, no person shall be asked to vacate his land and house until alternative land and house have been made available for him.

14·18 For purposes of rehabilitation, it is necessary that the new reclaimed areas are provided with essential modern amenities like safe drinking water, access roads, electricity, technical schools, etc., in compact model villages or townships and that facilities are provided for small and medium industries so that the new economy becomes an agro-industrial one, and does not remain the old exclusively agricultural one. The oustees should be encouraged to work on land reclamation and building operations to give them work and also a sense of belonging.

Efforts should be made to resettle the inhabitants of a group of villages in contiguous areas to preserve communal life.

14·19 The oustees should get preference in the matter of employment on the works connected with the projects. Technical institutes may also be set up to train skilled workers from among the oustees for taking up technical jobs on the projects.

14·20 The funds for reclamation of lands, transfer of families and their goods to the new settlements, providing a free housing plot for each family and internal roads and safe drinking water in the villages, should come from the normal compensation permissible under the Land Acquisition Act, liberally interpreted. But the cost of schools, technical schools, access roads (unless original access roads, schools, etc., get submerged), industries, electrification and irrigation works should form part of the State Plan under the various sectors, adequate additional funds being allocated for the purpose, as necessary.

Cost of projects

14·21 The cost of the projects in Madhya Pradesh, in the first phase, will be roughly Rs. 130 crores and, in addition, Madhya Pradesh will have to contribute a share of the cost of the power portion of the Navagam dam, which will be approximately Rs. 82 crores. Madhya Pradesh projects will thus cost about Rs. 212 crores during the next 10 years, for major schemes, in addition to some Rs. 50 crores which may be needed for medium and minor irrigation works.

Gujarat projects will cost about Rs. 310 crores for the high Navagam dam and canal system after making allowance for contribution to the power portion of the Navagam dam and power plant by the participating States.

Second phase of development

14·22 The construction of the first phase projects mentioned above would secure a storage of 24 million acre feet which is more than 80 per cent of the ultimate stage of 28·22 MAF and would make available water for all the major projects in the basin, both in Madhya Pradesh and Gujarat.

In the second and subsequent phases, the rest of the dams proposed by Madhya Pradesh, viz., Barwaha, Burhner and Kolar and any other which Madhya Pradesh may like to build for power or irrigation or both, may be built according to the availability of resources, the priorities being determined by that Government.

The Committee would suggest that preference should be given to the construction of Barwaha dam power and irrigation project in this phase to utilise the regulated supplies, flowing below Punasa, for generation of power and providing irrigation to culturable areas for the resettlement of oustees from the Punasa and Navagam reservoirs, particularly the latter.

Breakup of benefits and costs

14·23 The plan-wise break-up of irrigation and power development and the expenditure likely to be incurred in the next 30 years is indicated in Table 14·3 and is also shown graphically in Plates XI-1, XI-2 and XI-3. This is, of course, subject to work not being held up for shortage of funds, materials, etc.

TABLE 14·3

Phasing of Narmada basin development with Navagam+500

(Assuming preliminary construction works start in 1965)

		To the end of Plan				
	4th 1965—70	5th 1970—75	6th 1975—80	7th 1980—85	8th 1985—90	9th 1990—95
1	2	3	4	5	6	7
Irrigation (Lakh acres)						
Madhya Pradesh ..		10·0	20·0	35·0	50·0	65·0
Gujarat ..		10·0	25·0	40·0	45·8	45·8
Maharashtra ..		0·1	0·1	0·1	0·1	0·1
Rajasthan ..		0·4	1·0	1·0	1·0	1·0
Total ..		20·5	46·1	76·1	96·9	111·9
Water utilisation for irrigation (MAF).						
Madhya Pradesh ..		2·0	4·0	7·25	10·50	13·80
Gujarat ..		1·9	4·95	8·15	9·65	9·65
Maharashtra ..		0·1	0·10	0·10	0·10	0·10
Rajasthan ..		0·1	0·25	0·25	0·25	0·25
Total ..		4·1	9·30	15·75	20·50	23·80
Water going to sea (MAF)						
(*i*) After generation of power and unutilised for irrigation.	36·0	29·40	24·00	17·55	12·80	9·50
(*ii*) Unutilised either for power or irrigation.	36·0	7·15	6·11	6·02	5·95	5·60
Power MW @ 60 per cent L.F.[a]						
(*i*) Punasa and other schemes ..		554	1,198	1,063	843	793
(*ii*) Navagam—						
(*a*) River bed ..		1,000	1,000	725	430	245
(*b*) Canal bed ..		54	140	226	266	266
Total ..		1,608	2,338	2,014	1,539	1,304

(a) From the 8th Plan onwards, the load factor will go on decreasing and full capacity of installation utilised progressively as a peaking station. The load factor may drop down to 30 per cent or even lower.

1	4th 1965—70 2	5th 1970—75 3	6th 1975—80 4	7th 1980—85 5	8th 1985—90 6	9th 1990—95 7
Cost Rs. crores						
Madhya Pradesh						
Irrigation	40	80	125	200	275	351
Power	85	195	292	292	292	292
Gujarat						
Irrigation	40·0	90· 0	165· 0	240· 0	267· 0	267· 0
Power	18·0	30· 0	33· 0	33· 0	33· 0	33· 0
Maharashtra						
Irrigation	0·2	0· 5	0· 5	0· 5	0· 5	0· 5
Power	18·0	30· 0	33· 0	33· 0	33· 0	33· 0
Rajasthan						
Irrigation	..	5· 0	13· 0	13· 0	13· 0	13· 0
Total Irrigation	80·2	175· 5	303· 5	453· 5	555· 5	631· 5
Total Power	121	255	358	358	358	358
Navigation	10	30	50	60	60	60
Grand Total	211·2	460· 5	711· 5	871· 5	973· 5	1,049· 5

Financing of the plan

14·24 The financing of this Plan of integrated development is going to pose serious problems for the States concerned unless the large scale expenditure on this is treated as a loan outside the Plan provision for each State. Alternatively, the Central Government may take up the key major components of the Plan as a Central responsibility to begin with.

Once a decision has been taken to undertake a project or projects, the implementation thereof should proceed expeditiously with a view to obtaining earliest possible returns and thus raising additional resources to be invested in other parts of the Plan. It has been recognised that delays in implementation lead to mounting capital costs and diminishing returns.

An important source of revenue, so far as irrigation works are concerned, is available in the imposition of betterment levies and in adjusting water rates on the basis of cost of water supplied. The major resource will however accrue from power projects as stated in para. 14·3.

Fisheries

14·25 The development of fisheries has been receiving serious attention of all State Governments, because of the acute shortage of food, particularly, protective nutritious foods.

Artificial lakes likely to be created by the major projects and medium and minor irrigation works to be taken up by Madhya Pradesh and Gujarat, extending over an area of more than 20 lakh acres, and the extensive network of allied canal systems, will provide excellent facilities for pisciculture and substantial revenues to the States, if developed on scientific lines.

The yield per acre of fish from reservoirs in India is very low at present. For example, the yield of fish per acre from the Chilka Lake in Orissa is 75 lbs. and from the Hirakud reservoir only 0·5 lb per acre whereas it is as high as 2,000 lbs and above in a number of highly developed fish ponds in foreign countries. The Committee recommend that concentrated research should be undertaken with a view to raising this yield manifold.

With considerable improvement in the communication system, both by road and river navigation, brought about by the basin-wide development, it should be possible to easily transport fish and fish-products to numerous rural areas and to the large cities both within and outside the basin where large scale demand already exists. Besides adding to food production, the development of fisheries will also provide large-scale employment to people in various activities connected with fisheries.

Tourism

14·26 Madhya Pradesh is having large number of places of historical interest, besides many other centres of religious importance, in the Narmada basin. These attract a number of tourists and pilgrims from far off places; but lack of adequate communications and tourist facilities are a serious disincentive to any large-scale expansion of tourism.

The extensive developments envisaged under the integrated plan of development of the Narmada valley will improve communications and tourist amenities in the region, and the big and small reservoirs located among scenic surroundings will provide unusual attractions for the tourists.

If properly organised, tourism should provide a substantial source of revenue to the State and earn sizeable amount of foreign exchange.

CHAPTER XV

ORGANISATIONAL SET-UP FOR IMPLEMENTATION OF THE PLAN

15·1 The implementation of the Master Plan for the development of the water resources of the Narmada basin as indicated in Chapter XIV would necessitate investment of the order of Rs. 1,050 crores. The Committee have given careful consideration to the desirability of setting up a separate autonomous authority in the form of a statutory Corporation or a Company, for undertaking these development schemes on the Narmada river. The Committee's view on this aspect is discussed in the following paragraphs.

15·2 If a new autonomous authority is created, it will take considerable time to build up its engineering personnel to be able to undertake large engineering schemes. As experienced engineering personnel for undertaking river valley schemes is scarce in the open market, it will have to depend largely on the existing State organisations, such as the State Irrigation Departments and the State Electricity Boards of the States concerned, for loaning the services of such personnel. Past experience indicates that the staff is generally reluctant to accept service with autonomous bodies unless attractive financial benefits are offered, or advance promotion is given to relatively junior persons in various grades. Building up of a first rate organisation in these conditions will be difficult, take considerable time and will cause delays and some unavoidable element of inefficiency in the execution of schemes.

15·3 While Government will normally select the best personnel from amongst its services for manning the construction organisation of a scheme executed under their own control, they will be generally unwilling to spare their best officers for transfer to an independent organisation because of their own direct responsibilities to execute other works departmentally. This factor will also delay the formation of an efficient execution organisation under an autonomous authority.

15·4 On the power side, autonomous organisations have already been created in the States and at the Centre under the Electricity Supply Act (1948). These organisations did not suffer from the handicaps mentioned above as, in their case, there was wholesale transfer of staff from Government control to the control of the Boards. The State Electricity Boards are now well organised in most of the States whereas the Central Electricity Authority, although not yet organised to take up execution of projects in the field, is advancing already in this direction, and in the ultimate set-up, Regional Electricity Authorities are likely to be created to execute and operate projects on a regional basis under the directions and control of the Central Electricity Authority. To superimpose another autonomous authority over the present set-up will not offer any advantage ; it will only complicate the overall organisational structure and will unnecessarily add to the cost of the product and cause avoidable delays.

15·5 It is always of great advantage to associate the authorities, which have ultimately to operate the project, during the construction stage of the project as early as possible. On the Narmada river there are really two large storage schemes, viz., Punasa and Navagam, in Madhya Pradesh and Gujarat, respectively. The other schemes are relatively small and wholly lie in the State of Madhya Pradesh and may well be left for execution and operation to the Madhya Pradesh Government and the Madhya Pradesh State Electricity Board who may suitably phase these projects in their development plans. There will be no advantage in entrusting

the construction and operation of these schemes to an independent organisation, when suitable organisations in the irrigation and power field already exist. The creation of a separate autonomous authority for the construction stage only of the Punasa Project which also is wholly a Madhya Pradesh Project will increase the difficulties of recruiting staff, already mentioned in paras. 13·2, and 13·3, still further because of the temporary nature of such an organisation.

15·6 Setting up of a Government company, instead of an autonomous statutory authority, will have all the disadvantages mentioned above, to even a greater extent, as State Government's co-operation will be forthcoming to even a lesser degree than to a statutory Corporation. The creation of such a Company for the operation stage will have no advantage and will only add to the overhead costs, so far as the ultimate consumer is concerned.

15·7 The experience of D. V. C. which, in principle, is a well-conceived organisation, has not been too happy.

The Punasa Project and other Projects in Madhya Pradesh

15·8 Thus, although Punasa is quite a major project in the Narmada basin with far reaching effect on the development of projects in the lower reaches of the river, the Committee are of the view that the implementation of this as well as other projects in the State should be the responsibility of the Madhya Pradesh State Government. Early execution of the Punasa project is emphasised.

The State Government may consider the setting up of a Control Board and, if necessary, also a Consulting Board for the execution of the project.

The Navagam Project

15·9 The other major scheme on the Narmada river is the Navagam storage dam with its ancillary power plant and other works. The scheme of Navagam has necessarily to be a common scheme between the three partner States, namely, Madhya Pradesh, Maharashtra and Gujarat.

15·10 For most expeditious and efficient results, the execution of this project should be entrusted to Gujarat, in which the site is located, helped by such personnel as the other concerned States and the Centre may willingly spare.

15·11 To ensure common policy and control, a Control Board with representatives of the States concerned generally on the Bhakra pattern may be set up with responsibility for overall technical and financial control. (Annexure XV-1).

This Board may set up a Board of Consultants as on other major projects to advise it on technical and other matters which may be referred to it. This also may well be done on the Bhakra pattern.

15·12 The joint control, as indicated above, should apply to the construction of the dam and power houses and appurtenant works only.

The Control Board, with suitable modification in its constitution, may also exercise necessary control over the operation of the dam and the power plant after completion.

15·13 Irrigation under Navagam Project will be all in Gujarat except about one lakh acres at the tail in Rajasthan. The construction of the canal system and other ancillary works should, therefore, remain the sole responsibility of the Gujarat State Government. The State Government may consider the setting up of a Control Board of its own for the execution of the irrigation part of the Project on which Rajasthan may be represented.

15·14 The State Governments of Gujarat and Rajasthan may also consider the setting up of a Control Board for the execution of projects under the Mahi-Sabarmati complex.

Training of Engineers

15·15 The Committee strongly recommend that the engineers charged with the responsibility of execution of works should be given ample opportunity for visiting major construction works in the country, such as, Beas units I & II, Ramganga, Nagarjunasagar, Rajasthan canal, Sabaragiri project in Kerala, Rana Pratap Sagar and Kotah dams on the Chambal, the many hydroelectric projects in Madras, etc., etc. This will pay handsome dividends.

ANNEXURE XV-I

Government of India, Ministry of Works, Mines and Power Resolution No. DWII-22(3), dated the 25th September 1950 as amended from time to time.

At a conference held on the 25th September 1950, in New Delhi at which the representatives of the Central Government and the State Governments of Punjab (I), PEPSU, Rajasthan and Bilaspur were present, it was decided to set up a Bhakra Control Board and a Bhakra Advisory Board to ensure efficient, economical and early execution of the Bhakra Nangal Project including all connected works in Punjab (I), PEPSU, Rajasthan and Bilaspur. The terms of agreement arrived at between the various Governments concerned are set out below:—

Constitution of the Bhakra Control Board and Bhakra Advisory Board

With a view to ensure efficient, economical and early execution of the Bhakra Nangal Project, including all connected works in Punjab (I), PEPSU, and Rajasthan, the Central Government and the State Government of Punjab (I), PEPSU and Rajasthan agree to set up a Bhakra Control Board and a Bhakra Advisory Board as described below. They also agree that the Control Board should take over all charge of all technical and financial aspects relating to the construction of the project, the actual work of construction being carried out, under the direction of the Control Board, by the Chief Engineer concerned of the State in which the work lies, except that in respect of the construction of the Bhakra Dam and appurtenant works which lie partly in Punjab and partly in Bilaspur, the work will be done by the Chief Engineer, Punjab.

2. The participating State Governments further agree to delegate powers to their respective Chief Engineers to contract for works, supplies and services at the direction of the Control Board; such contracts to be executed as on behalf of the State Governments concerned.

3. The Bhakra Control Board will consist of the following:—

(*i*) Governor of Punjab	..	Chairman
(*ii*) Secretary to the Government of India, Ministry of Irrigation & Power.		Vice-Chairman
(*iii*) Joint Secretary, Ministry of Finance, Government of India	..	Member
(*iv*) Chairman, Central Water & Power Commission	..	Member
(*v*) Secretary to the Government of Punjab, Irrigation & Power Department		Member
(*vi*) Secretary to Government of Punjab, Finance Department	..	Member
(*vii*) Secretary to the Government of Rajasthan, Irrigation & Power Department.		Member
(*viii*) Chief Secretary, Himachal Pradesh	..	Member
(*ix*) General Manager, Bhakra Dam, Punjab	..	Member
(*x*) Chief Engineer, Irrigation, Rajasthan	..	Member
(*xi*) Chairman, Punjab State Electricity Board	..	Member
(*xii*) Chairman, Rajasthan State Electricity Board	..	Member

The Board will be assisted by a whole-time Secretary (an officer preferably of the rank of Superintending Engineer) and a Deputy Secretary (an officer of the rank of Deputy Secretary or Under-Secretary, Finance Department) and such other staff as may be necessary with headquarters at Delhi till otherwise decided by the Board.

The Chief Engineer concerned with any part of the project will be invited to attend as Adviser when matters relating to his part of the Project are under consideration of the Control Board.

4. In particular and without prejudice to the generality of the provision in paragraph 1 above, the Bhakra Control Board shall—

(*i*) scrutinise the estimate of the project prepared by Punjab, advise necessary modifications and recommend the estimate for administrative approval of the Government concerned;

(*ii*) examine and approve from time to time the delegation of such powers both technical and financial, as it may deem necessary for the efficient execution of the project to the Chief Engineers, Superintending Engineers, Executive Engineers and Subdivisional Officers engaged in the execution of the project;

(*iii*) examine and where necessary, lay down specifications and schedule of rates for various classes of work with a view to sound and efficient execution of the project;

(*iv*) approve all sub-estimates and contracts, the cost of which exceeds the powers of sanction of the Chief Engineers;

(*v*) approve all proposals for award of work or supplies on contract other than those based on public tenders and on detailed quantitative estimates and works allotted on work order basis on schedule rates;

NOTE (1)—Where total financial liability under a contract is definitely ascertainable at the time of placing the contract and where the contract itself is the result of a public or limited call for tenders, prior submission of the proposals to the Control Board will not be necessary so long as the contract is otherwise within the powers of sanction of Chief Engineers.

NOTE (2)—This will not affect the powers delegated from time to time to the Chief Engineers, Superintending Engineers, Executive Engineers and Subdivisional Officers.

(*vi*) frame rules as to delegation of powers and procedure for the purpose of carrying out its business.

(*vii*) decide, after ascertaining the views of the Bhakra Advisory Board, if necessary, the programme of construction of different parts of the project in all the participating States, keeping in view the funds available, the economics of the project and the desirability of obtaining quick results ;

(*viii*) decide, after ascertaining the views of the Bhakra Advisory Board, if necessary, on the stage development of water power and the withdrawals of water from the reservoir during the construction period for irrigation and power purposes with a view to securing best use of water available;

(*ix*) receive monthly progress reports both as to works and expenditure in a prescribed form from the Chief Engineers, review the progress of different units of the project and lay down steps to be taken to expedite the work.

5. The Bhakra Control Board will be assisted by an Advisory Body which will have the following constitution and functions :—

Constitution

(*i*) Chairman, Central Water & Power Commission

(*ii*) Financial Advisor and *ex officio* Joint Secretary, Ministry of Irrigation & Power, Government of India, or his representative.

(*iii*) Member, Hydroelectric, Central Water & Power Commission

(*iv*) Secretary, Finance, Punjab

(*v*) General Manager, Bhakra Dam, Punjab

(*vi*) Chief Engineer, Bhakra Canals, Punjab

(*vii*) Chief Engineer, Electricity, Punjab

(*viii*) Finance Secretary, Rajasthan

(*ix*) Chief Engineer, Irrigation, Rajasthan

(*x*) The Chief Secretary, Himachal Pradesh

The Secretary and Deputy Secretary of the Bhakra Control Board will also act as Secretary and Deputy Secretary respectively of the Bhakra Advisory Board.

Functions

The functions of the Board will be to advise the Central and State Governments concerned and the Bhakra Control Board on all aspects of Bhakra Nangal Project and will include the following :—

(*i*) to arrange discussions for facilitating mutual appreciation of the respective view points of the participating Governments in regard to overall plan, the programme and the place of construction ;

(*ii*) to examine the programme and progress on the project from time to time in the participating States ;

(*iii*) to resolve differences arising at technical level on the suitability, adequacy or feasibility of any important part of the project ; only such differences will be taken up as are admitted by the Chairman, Central Water & Power Commission.

(*iv*) to advise, at the request of the State Governments concerned, on the internal distribution of the allocated supplies of water from Bhakra to different areas with a view to the optimum utilisation of such supplies.

6. The meetings of the Advisory Board shall ordinarily be held once every three months and those of the Control Board monthly or as necessary.

COMPOSITION OF THE BHAKRA BOARD OF CONSULTANTS

1. Dr. A. N. Khosla	..	Chairman
2. Shri S. D. Khunger	..	Member
3. Shri S. S. Kumar	..	Member
4. Shri Moti Ram	..	Member
5. Shri Karnail Singh	..	Member
6. Shri Kanwar Sain	..	Member
7. Shri M. R. Chopra	..	Member

CHAPTER XVI

SUMMARY

CHAPTER I

16·1 The Narmada Water Resources Development Committee was appointed by the Government of India, Ministry of Irrigation & Power, under their Resolution No. DW. II-32(4)/64, dated the 5th September, 1964. The terms of reference required the drawing up of a Master Plan for the optimum and integrated development of the Narmada water resources ; the phasing of its implementation for maximum development of the resources and other benefits ; the examination in particular of Navagam and alternative projects and determining optimum reservoir level or levels ; suggesting the distribution of benefits and costs among the States ; and making recommendations on any other ancillary matters.

16·2 The Committee was asked to submit its report within four months but as its work could not be completed within this time, the term was extended by stages to the 30th September, 1965.

CHAPTER II

16·3 The Committee held discussions with representatives of Madhya Pradesh, Maharashtra, Gujarat and Rajasthan in December, 1964 and requested them to send their proposals for the development of the Narmada. These proposals were sent to the other State Governments for their comments. Extensive studies about hydrology and power generation under various conditions were made by the C.W. & P.C. and the Committee's Secretariat and the results were made available to State Governments concerned for their remarks.

16·4 During its tour of Madhya Pradesh and Gujarat in April, 1965 and visits to Bombay and Jaipur in June, 1965 and July, 1965, respectively, the Committee saw the important dam sites and had detailed discussions with Chief Ministers, and other ministers and officials of the State Governments.

16·5 Further talks were held by the Chairman of the Committee with Chief Ministers of Madhya Pradesh and Gujarat at Bhubaneswar on the 21st July, 1965 and 11th August, 1965, respectively.

CHAPTER III

The Narmada River

16·6 The Narmada river rises in the Amarkantak plateau in Madhya Pradesh at an altitude of over 3,400 ft. and falls into the Gulf of Cambay after traversing a course of 815 miles through Madhya Pradesh, Maharashtra and Gujarat. The catchment area is about 38,000 sq. miles. During its course in Madhya Pradesh, the Narmada passes through hilly country and gorges with large intervening areas of fertile plains. Below the last gorge it emerges at Navagam into the flat Gujarat plain. The respective catchment areas above Navagam are Madhya Pradesh 33,150, Maharashtra 594 and Gujarat 226 sq. miles. Good sites are available in the gorges for construction of storage dams.

CHAPTER IV

Present stage of Investigations

16·7 In 1946, Shri A. N. Khosla, Chairman, Central Waterways, Irrigation & Navigation Commission, suggested consideration of unified multipurpose development of the Narmada basin. In the same year the Commission was asked by the Governments of Central Provinces and Bombay to carry out investigation for development of irrigation, power, navigation, etc. in the Narmada basin. The Commission carried out a reconnaissance of various sites and prepared estimates for detailed investigations of seven projects which on completion were expected to irrigate 40 lakh acres and to generate one million KW of power.

16·8 In 1948, the Government of India appointed an *ad hoc* Committee under the Chairmanship of Shri A. N. Khosla, then Chairman of Central Waterways, Irrigation & Navigation Commission, to scrutinise the estimates referred to above and suggest priorities.

16·9 This Committee expressed the opinion that the Narmada had a large potential for development including irrigation of 37 lakh acres of land, generation of over one million KW of power and extending navigation from the sea up to and even beyond Hoshangabad.

16·10 Because of shortage of staff and materials, the *ad hoc* Committee recommended detailed investigation of only four projects, namely, Bargi, Tawa and Punasa in Madhya Pradesh and Broach irrigation in Gujarat. The Committee also desired that the cost of collection of data about silt and discharges at various places—meteorological, mineral, navigational and economic surveys—should also be included in the estimates for investigations.

16·11 In accordance with the advice of the *ad hoc* Committee, the Government of India sanctioned in 1949 estimates for investigations of the above four projects. The work was taken up by the Central Waterways, Irrigation & Navigation Commission (which in 1951 became the Central Water and Power Commission or C.W. & P.C.). Project reports for all except Bargi (work on which was suspended for lack of funds) were prepared. Bargi was taken up again in 1960 and the project report completed in 1963. The C. W. & P. C. have also prepared project reports for Barna and Kolar in Madhya Pradesh.

16·12 At a meeting in the C.W. & P.C. at New Delhi on 24th April, 1957, the representatives of Madhya Pradesh and Bombay agreed to the investigation of the irrigation and power possibilities of other sites on the Narmada between Punasa and Broach, the cost being shared by the two States. Three sites, namely, Barwaha, Hiranphal and Keli were selected.

16·13 In 1959, the Keli site was dropped at the instance of the then Bombay Government as it would be submerged by the dam proposed lower down at Navagam.

16·14 The State Government of Madhya Pradesh have, through their own agency, completed the report for Sitarewa project. No other detailed investigations have been done so far in this State for development of Narmada basin.

Areas for Irrigation & Water Requirements

Madhya Pradesh

16·15 In February, 1961, at a meeting held in C.W. & P.C. it was accepted that Madhya Pradesh would irrigate an area of about 30 lakh acres of land from the Narmada system above Punasa and would require 6·0 MAF of water. Another one MAF would be needed for an area of 2,18,000 acres to be irrigated from the Barwaha reservoir proposed below Punasa. The total was thus 7·0 MAF

These figures were subsequently raised as under :—

(*a*) In 1963, 46 lakh acres of irrigation and 12 MAF of water in Madhya Pradesh Government publication " Irrigation & Power potential of Madhya Pradesh rivers, 1963 ".

(*b*) In 1965, 50 lakh acres of irrigation and 15 MAF of water in "A note on Agro-economic aspect of Irrigation Potential in Narmada Valley, Madhya Pradesh", issued by the State Electricity Board.

(*c*) In 1965, 77·5 lakh acres of irrigation and 23·75 MAF of water in the Madhya Pradesh Master Plan for development of Narmada water resources submitted to the Committee. It has been mentioned in this Plan that the area and water required were expected to rise even higher in future.

Former Bombay and now Gujarat

16·16 In the 1956 Broach Irrigation project prepared by the C. W. & P. C. it was estimated that an area of 10·97 lakh (13·3 lakh gross) acres requiring 2·8 MAF would be irrigated in Gujarat State from the Narmada.

16·17 In 1957 the C. W. & P. C. increased these figures to 22·7 lakh acres gross and 4·8 MAF by raising the FRL of the dam at Navagam to +300 and proposing construction of one low level and one high level canal to serve larger areas.

16·18 In 1963 project the scope was greatly increased, the Navagam dam FRL was raised to +425 and a single high level canal was proposed with FSL +300 to irrigate 40 lakh acres requiring 12 M A F. A part of the Little Rann of Kutch was included in the command.

16·19 In the 1965 technical memorandum submitted to the Committee, the Navagam dam FRL was raised to +490 and 29 per cent of double cropping was assumed for the area of 34·74 lakh acres to be irrigated and 13·20 MAF of water provided to meet these requirements.

16·20 Later in 1965, an addition of 4·35 MAF was made to the water demand, at the suggestion of the present Narmada Water Resources Development Committee. Of this, 2·45 MAF was to provide for irrigation of 4·5 lakh acres in the Great Rann of Kutch bordering on Pakistan and 1·9 MAF for including in Narmada command an area of 6·57 lakh acres which was originally to receive irrigation from the Mahi river, the Mahi water so saved to be transferred to border areas of Rajasthan.

16·21 The acreage for irrigation thus came to 46·8 lakh acres and water demand to 17·55 MAF

Maharashtra

16·22 Maharashtra have no proposals at present for using Narmada water for irrigation. They expect to use ultimately 0·1 MAF to do some lift irrigation in local areas.

Rajasthan

16·23 Rajasthan in their memorandum have asked for water for irrigating more than a million acres in their territory. They have suggested raising of the Navagam dam FRL and of the Navagam canal to bring as much of it as possible within flow command of the canal.

CHAPTER V

Hydrology

16·24 The Narmada is the largest river in Central India but no systematic gauge and discharge observations were made before 1947 to determine its runoff at any place.

Discharge Observations

16·25 Eleven discharge observation stations were set up by the Central Waterways, Irrigation and Navigation Commission (now C. W. & P. C.) in 1948-49 on the main river and some of its important tributaries at places where information about coming projects was required. These were handed over in 1953 to the State Governments which continued the work at some sites but dropped others. Discharge observations are being made regularly from 1948 onwards at only three sites on the main Narmada. These are Jamtara (for Bargi dam), Mortakka (for Punasa dam) and Gardeshwar (for Navagam dam). The catchment areas, the number of rain gauges and mean annual rainfall for these sites are given below:

Period	Jamtara (Catchment area 6400 sq. miles)		Mortakka (Catchment area 25942 sq. miles)		Gardeshwar (Catchment area 34496 sq. miles)	
	No. of rain gauges in catchment	Mean annual rainfall inches	No. of rain gauges in catchment	Mean annual rainfall inches	No. of rain gauges in catchment	Mean annual rainfall inches
1948—1962 ..	11	57·10	45-53	50·33	57-69	46·04
1931—1962 ..	8-11	60·17	41-53	53·53	49-69	48·59
1915—1962 ..	5-11	61·30	29-53	52·86	34-69	47·82

16·26 The cross section of the river at all these places is plotted every year to give the areas for various depths and the velocities are observed by current meter placed at 0·6 of the depths or by surface floats.

Reduction co-efficient

16·27 The velocity given by surface floats was multiplied by a co-efficient of 0·8 at Mortakka and 0·78 at Gardeshwar to obtain the mean velocity. Gujarat's comparative observations with current meter and surface floats have established that the reduction co-efficient should not be less than 0·85.

This point was studied in great detail by the Central Water & Power Commission and they recommended that 0·85 should be accepted. The Madhya Pradesh Government also agreed with this view.

16·28 The runoff figures for both these discharge sites have, therefore, been corrected by changing the co-efficient to 0·85.

Rainfall

16·29 Rainfall data for the raingauges in the catchment is available from 1891 onwards but the number of rain gauges up to Gardeshwar has increased from 21 in 1891, to 32 in 1911, 48 in 1931, 59 in 1951 and 69 in 1961. The figures for mean rainfall are, in the circumstances, less reliable in the earlier years.

16·30 The Committee, therefore, decided to take the period from 1915 onwards for calculating the runoff to be adopted in their proposals.

Runoff

16·31 The entire catchment down to Gardeshwar was divided under the Committee's instructions into the following four zones for runoff studies made by the C. W. & P. C.:—

(1) Catchment area up to Jamtara;

(2) Catchment area of Tawa river up to Tawa bridge;

(3) Catchment area between Jamtara and Mortakka excluding Tawa; and

(4) Catchment area between Mortakka and Gardeshwar.

16·32 The C.W. & P.C. worked out a linear relationship between rainfall and runoff for each of these zones on the basis of actual data from 1948 onwards and applied this relationship to obtain the runoff for each zone for earlier years for which only rainfall figures were available.

16·33 The table below shows the average annual runoff based on the period 1915 to 1962 at different dependabilities at the various sites :—

Percentage dependability	Yield in MAF			
	Jamtara	Tawa	Punasa (Mortakka)	Navagam (Gardeshwar)
50 per cent ..	8·72	3·65	28·83	35·94
75 per cent ..	6·68	2·57	23·23	28·92
90 per cent ..	4·84	1·59	18·18	22·59

16·34 Madhya Pradesh objected to this period of 1915 to 1962 as the basis for calculations and suggested that the runoff should be based only on the years for which actual data were available (i.e., 1948 onwards) and if earlier years were to be included, the period 1891—1911, which had some bad years, should also form part of the series.

16·35 Gujarat desired that the entire catchment should be regarded as one unit for runoff calculations and should not be split up into zones which would increase the chances of error owing to mal-distribution of raingauges.

16·36 The Committee, however, consider the calculations of C. W. & P. C. to be reliable and have accepted them.

CHAPTER VI

State Proposals

Madhya Pradesh

16·37 In their Master Plan, Madhya Predesh have divided the Narmada basin into the following four zones :—

(*i*) Upper hilly areas with annual rainfall of over 55 inches generally and over 65 inches in some places.

(*ii*) Upper plains with annual rainfall of 55 to 40 inches.

(*iii*) Lower plains with annual rainfall of 40 to 25 inches

(*iv*) Lower hilly areas with annual rainfall of about 30 inches.

16·38 The total area of the basin is 212·33 lakh acres of which 128·22 lakh acres is culturable and the actual area sown at present, 82·2 lakh acres.

16·39. The Master Plan envisages irrigation of 77·5 lakh acres or 94·3 per cent of the sown area. Of this, 26,74,000 acres are to be irrigated from specified major projects and the rest from medium and minor projects. The latter are yet in a speculative stage. They have neither been identified nor surveyed.

16·40 The demand for water on full development is estimated to be 23·75 MAF based on crop pattern and deltas as envisaged by that Government.

16·41 The work on Tawa and Barna projects, already in hand, is to be pushed forward. The State envisages starting work on Punasa and Bargi (power only) projects as soon as possible. The next phase will be the construction of Rosra and Burhner and later of Hiranphal projects.

Intensive activity is also envisaged on medium and minor works at the same time so that, in a period of 10 years, irrigation facilities can be provided for about half the total area.

16·42 The State Government anticipate that on full development of irrigation 344 MW of power at 100 per cent load factor will be generated in 75 per cent dependable flow years and 575 MW at 100 per cent load factor in 50 per cent dependable flow years.

16·43 The total cost of development is estimated to be of the order of Rs. 800 crores.

Gujarat

16·44 The Gujarat Government have, in their memorandum, pointed out that semi-arid conditions prevail in 18 per cent of the area of the State while in another 55 per cent, the rainfall is low to average, and mentioned that, by the end of 3rd Plan, the irrigated area would rise to only 9·39 per cent of the total and that more than 80 per cent of this would be from surface wells. Also, full utilisation of water of the Mahi, Sabarmati and Tapi rivers had already been planned, so that the Narmada was the only source left for extending irrigation.

16·45 The memorandum includes proposal for building a dam on the Narmada at Navagam and taking off a canal on the right bank with FSL+300 to command a gross area of 87·64 lakh acres of which 66·40 lakhs is cultivable. The actual area to be irrigated is placed at 34·74 lakh acres. To this has to be added 6·57 lakh acres of land which is in command of Mahi canals but can be easily irrigated from the Navagam canal and another 4·5 lakh acres in the Great Rann of Kutch near the Gujarat-Pakistan border, thus bringing the total to 45·8 lakh acres. Of this, about 6·8 lakh acres would have to be irrigated by lift in Kutch and Saurashtra, mostly with the power generated for this on the same canal (Saurashtra Branch) at its 70′ fall higher up.

16·46 The water required for irrigation is estimated at 17·55 MAF on the basis of the crop pattern, water depths and intensities, envisaged by the State Government, on full development.

16·47 The memorandum envisages generation of 679 MW of power at 60 per cent load factor in the river bed power station and at the head of Navagam canal, on the assumption of 6·8 MAF water utilisation for irrigation in Madhya Pradesh and 13·08 MAF in Gujarat, exclusive of requirements of Mahi areas (now to be fed from the Narmada) and Great Rann of Kutch.

Maharashtra

16·48 Maharashtra have asked for reservation of only 0·1 MAF of water for irrigation.

16·49 They, however, want at least 1,000 MW of power at 60% LF to meet shortage anticipated in future years.

Rajasthan

16·50 Rajasthan want water for about 11·5 lakh acres of desert areas on the Rajasthan-Pakistan border.

16·51 Only about one lakh acres of this can be irrigated by flow from the Navagam canal FSL+300 and the remainder has to receive irrigation from the Mahi-Sabarmati complex.

CHAPTER VII

Committee's Assessment of water required for irrigation

16·52 The Committee are satisfied that all the 128·22 lakh acres of land shown as cultivable in the Narmada basin would not be available for cultivation. If allowance is made for permanent pastures, miscellaneous tree crops and groves, areas submerged by large and small reservoirs and catchments of medium and

minor works which, by themselves, will remain out of command, only about 83 lakh acres would be left, so that the actual annual irrigation can, at the outside, be taken as 65 lakh acres.

16·53 According to the crop pattern and delta (2·4 ft.) accepted by the Committee, the water required for 65 lakh acres, inclusive of reservoir losses, would be 15·6 MAF.

16·54 The Committee accept the figure of 45·8 lakh acres for irrigation in Gujarat and about one lakh acres in Rajasthan (which can be commanded by flow).

16·55 The requirement, according to Committee's crop pattern and delta (2·4 ft.), would be 10·9 MAF, inclusive of reservoir losses.

16·56 The Maharashtra demand for irrigation is very small, viz., 0·10 MAF. The Committee accept it in full.

16·57 In calculating the water required for irrigation, the Committee have accepted for all the States a uniform delta of 2·4 ft. at canal head, inclusive of losses in channels and storage reservoirs, on the grounds that (*a*) in Madhya Pradesh, despite relatively heavier rainfall, there will be greater drainage outflow from the fields and also there is less of plain areas to build up sub-soil water reservoirs, and (*b*) in Gujarat, with lighter soils and relatively less rainfall, the areas are mostly plain and, therefore, capable of large-scale sub-soil water reservoirs to be built up, providing substantial quantities of water for irrigation by pumping.

16·58 The Committee are satisfied that, with the carryover capacity in the reservoirs proposed, the Narmada would have enough water to meet full demands for irrigation in most years. Recommendations have, however, been made for sharing the water between Madhya Pradesh on the one hand and Gujarat and Rajasthan on the other in bad years. Under this scheme of sharing after full development, Madhya Pradesh would have a slight shortage and Gujarat and Rajasthan about 30 per cent shortage in only about one year out of 20.

CHAPTER VIII

Integration of resources of Mahi and other rivers with Narmada system

16·59 The Committee have studied the possibility of integrating the water resources of the Mahi, Sabarmati and other rivers and streams with the Narmada system. Gujarat is developing or has plans to develop resources of rivers other than the Mahi for benefit of local areas which have no other means of irrigation.

16·60 The only contribution possible from all these streams, taken together, to the Narmada system is limited to about 0·34 MAF.

16·61 In the case of the Mahi, the Committee have recommended that the 6·57 lakh acres of land served by the Mahi canals in Gujarat should be transferred to the Navagam canal and the storages of Banswara dam (in Rajasthan) and Kadana dam (in Gujarat), which are about to be sanctioned, and of the Baneshwar and Anas dams in Rajasthan, which are under investigation, should be constructed for irrigation and power jointly by Rajasthan and Gujarat. The benefits would be shared in the ratio of 2 for Rajasthan and one for Gujarat subject to such marginal adjustments as may be mutually agreed upon.

CHAPTER IX

Navigation

16·62 The construction of the Navagam canal and a number of dams will ensure adequate depth of water in long reaches of the canal and the Narmada river. By providing adequate headway under the canal bridges (the canal has a very flat gradient) and a number of lift dams and locks, where necessary, it should be possible to make the Narmada river navigable from the sea at the Kandla port or Broach to and even beyond Bargi dam.

16·63 The Committee would like to stress that the structures on the main Navagam canal should be designed to allow for navigation; that the distributary leading to Kandla port should be provided with navigation lock; that suitable lockage and lift arrangements be provided in the canal and at the various dams; and that the completion of these should synchronise with the completion of the canal and dam structures so that navigation may be possible directly the major works of the plan get completed.

16·64 The extra cost involved in providing navigation facilities may be charged to the project concerned and the revenues on that account credited to that project.

A better alternative would, however, be for the Central Government (Ministry of Transport) taking the entire responsibility for the cost of navigation work and sharing the revenues with the State Governments on an agreed basis.

CHAPTER X

Flood Control

16·65 The Committee have made no specific provision for flood control. They are of the view that the storage capacity of the various reservoirs, particularly of the terminal reservoir at Navagam (FRL+500), would be adequate to reduce the peak discharge to relatively harmless proportions and that the severe floods, which periodically cause heavy damage in the Broach district of Gujarat, would cease to be a problem.

CHAPTER XI

Priorities in utilisation of Narmada water

16·66 The Committee have given the highest priority to irrigation because of the serious food shortage and the heavy drain of foreign exchange involved in importing foodgrains ; and have, in the interest of national security and greater food production, stressed the necessity for taking water to the rainless and uninhabited areas of Kutch and Rajasthan bordering Pakistan, so that hardy peasants can be settled there permanently.

16·67 The 36 MAF of water in the Narmada and its tributaries above Navagam will irrigate over 11 million acres in Madhya Pradesh, Gujarat and Rajasthan and generate over two million KW of power and still have 5 to 6 MAF flowing to the sea. Assured irrigation would encourage cultivators to adopt better agricultural practices, use fertilisers, improved seeds and raise agricultural output manifold.

16·68 The Narmada has enough water to meet all irrigation and power demands for at least the next 25 years and still generate large amounts of electric power. At that stage, the hydro stations will progressively become peaking stations with load factors declining to 30% or lower and thus use the installed capacity almost fully. On full development, some adjustment between irrigation and power may be necessary in lean years only to ensure that power production is not unduly reduced. By that time, it is expected that there will be substantial additions to river supplies through regeneration and also it would be possible to help the irrigation system by extensive pumping from the underground reservoir, particularly, in Gujarat. Large-scale pumping combined with adequate drainage would keep the spring level under control, avoid waterlogging and damage to land and add to the water supplies available for irrigation and power development from surface reservoirs.

16·69 The Punjab and Rajasthan provide an instructive parallel. The three rivers of the Punjab, namely, Sutlej, Beas and Ravi, have between them, a mean annual runoff of 32·8 million acre feet for an ultimate irrigation of about 12·5 million acres with rainfall varying between 10" and 30". Waterlogging has already assumed serious proportions over large areas of irrigated lands in the Punjab.

CHAPTER XII

Location and Optimum levels of Terminal Reservoir or Reservoirs on Hiranphal-Navagam gorge.

16·70 Madhya Pradesh have, in their Master Plan, proposed a dam at Hiranphal FRL+465 (MWL+470) and another dam at Jalsindhi FRL+355 and tail water level+210. Maharashtra proposed a high dam at Jalsindhi FRL from+460 to+500 and tail water+210, but later they accepted the Madhya Pradesh proposal. Gujarat proposed a dam FRL+490, tail water level+80, at Navagam.

16·71 The Committee have made extensive studies to ascertain the benefits available with various levels and combinations of dams and have come to the conclusion that the best location for the terminal dam is Navagam and its optimum full reservoir level (FRL)+500 for storage, adequate carryover, power generation, flood control and minimising wastage of water to the sea.

FSL of Navagam Canal

16·72 Gujarat proposed that the Navagam canal should have FSL+300 at head to command all the areas that they wish to irrigate in the State up to their border with Rajasthan, including reclamation and irrigation of Little Rann of Kutch.

Reclamation and irrigation in the Great Rann of Kutch was subsequently added at the instance of the Committee.

16·73 Maharashtra originally recommeneded that the FSL of this canal should be+185/190 which would be able to irrigate the larger part of the area included by Gujarat. The balance, according to them, could be irrigated by pumping from this canal. In a later memorandum, Maharashtra stated that after the full utilisation for irrigation proposed in Madhya Pradesh Master Plan, the amount of water reaching Gujarat would be severly limited and that it would be just enough to meet the flow command of the FSL.+185/190 canal, so that a canal with higher FSL would not be justified.

The Committee feel that it will be wasting precious electrical energy in irrigatng vast areas by lift, when flow irrigation could easily be given. According to Committee's estimate, the power required for lift would be of the order of 200 MW, which would just not be available. Moreover, to the cost of power (if it were available) would have to be added the cost of pumping installation, pipelines, carrier channels, etc., making it prohibitive. The FSL of +185/190 would also not be able to take water to the areas of Great Rann of Kutch and Rajasthan bordering Pakistan, which latter is an essential feature of the Plan.

16·74 The Committee are satisfied that there would be enough water to irrigate an area of 46·8 lakh acres in Gujarat and Rajasthan and, for that, the FSL of this canal at head must be +300. The Committee, therefore, accept FSL+300 for the Navagam canal.

Installed capacity at Navagam

16·75 Taking into consideration the power that would be generated at Navagam +500 during the various stages of irrigation development, the Committee have come to the conclusion that the installed capacity at the river bed power station and the canal power station should be 1,000 MW and 240 MW, respectively, with one standby unit in each.

Chapter XIII

Allocation of cost of Navagam dam between irrigation and power

16·76 The Committee have recommended that this should be on the basis of water utilised by each in the mean year of development which has been taken to be 1985, i. e., 20 years after start of construction. This presumes that authority to start essential preliminary works is given in 1965. The actual amounts chargeable for various FRLs from +465 to +500 worked out as follows:—

S. No.	FRL	Total cost of Dam	Cost chargeable to			
			Irrigation	Percentage	Power	Percentage
1	+500	111·0	42·0	37·8	69·00	62·2
2	+490	101·0	39·0	38·6	62·00	61·4
3	+480	91·0	36·0	39·6	55·00	60·4
4	+465	77·0	32·0	41·6	45·00	58·4

Allocation of power benefits and costs between Madhya Pradesh, Maharashtra and Gujarat

16·77 The Committee have assumed that Madhya Pradesh is entitled to get as much power as it would have got if a high dam FRL+465 had been constructed at Hiranphal in their own territory and that the other two States should share the balance equally.

Calculations on this basis for Navagam FRL+465 show that the shares in the mean year 1985, would be as under :—

Madhya Pradesh		Gujarat		Maharashtra
1·64	:	1	:	1

16·78 In view of the fact that almost the entire submersion of cultivable lands by Navagam reservoir would be in Madhya Pradesh, the Government of which would have to face the problems of land acquisition and rehabilitation of oustees, the Committee proposed that the share of Madhya Pradesh should be raised to 2·0. For higher FRL of Navagam, these problems would progressively increase and the share of Madhya Pradesh would, therefore, have to be raised further to 2·15 at FRL+480, to 2·3 at FRL+490 and to 2·5 at FRL+500.

16·79 The Committee propose further that the cost of the power portion of Navagam dam, the power plant and transmission link to Hiranphal should be shared by the three States in proportion to the power allocated to them.

16·80 Tables have been prepared to show the power that would be available to each State for full reservoir levels of Navagam +465 to+500 at various stages of development from the year 1975 to 1995. The cost and the annual revenue expected have also been indicated.

16·81 The Committee do not, on principle, accept the demand that a dam lower down the river should pay compensation to upper dam for benefits derived from regulated releases of water from the latter. In view, however, of the special circumstances of the case, they propose that the Navagam dam should afford a credit of a fixed sum of Rs. 13 crores to Madhya Pradesh for regulated releases from Punasa dam which is to be adjusted against the Madhya Pradesh share in the cost of Navagam dam, power plant and appurtenant works. Calculations have been given to show how this figure has been arrived at.

16·82 Proposals have been made by the Committee for sale to the other partners of power which may at any time be surplus to requirements of one of the partners.

16·83 The Committee recognise that Rajasthan have no claimto partnership in Narmada basin power generation but in view of the shortage and lack of resources in that State, they recommend a reasonable allocation to it from the common pool as a beneficiary. The amount may be determined by the three partners.

CHAPTER XIV

Committee's plan of development

16·84 In drawing up the programme of basinwise development, the Committee had the following basic considerations in view :—

firstly, the acute shortage of food and the imperative need for accelerated pace of irrigation development to provide more food ;

secondly, the all-round power shortage which is hampering the progress of industries as well as rural development including rural industries and pumping for irrigation ;

thirdly, the necessity for raising financial resources, possible mainly through power development, for investment in other essential projects; and

fourthly, the reported decision of the Planning Commission to make massive allocation for irrigation and power during the Fifth, Sixth and subsequent Plans.

16·85 It has been assumed (*a*) that irrigation would develop at a rate much faster than that justified by current experience and (*b*) that owing to acute shortage and in view of the relevant load forecasts, the power generated would be absorbed as soon as it is made available.

First phase of development

16·86 The Committee accordingly recommend for the first phase —

(*a*) that work on the Tawa and Barna projects, which is already in progress, should be expedited ;

(*b*) that the Bargi project (both power and irrigation) and Punasa project in Madhya Pradesh, and Navagam project in Gujarat should be taken up ;

(*c*) that the Navagam canal should be constructed in one stage and not in three stages as envisaged by Gujarat, so as to make water available as early as possible for reclamation of saline lands in the two Ranns of Kutch and, in particular, for carrying irrigation to Kutch and Rajasthan areas bordering Pakistan ;

(*d*) that work on medium and minor projects in Madhya Pradesh should proceed as quickly as resources permit ; and

(*e*) that action should be taken simultaneously with the construction of storage works, to make adequate arrangements for the rehabilitation and resettlement of oustees from areas to be submerged by the proposed reservoirs. It is desirable that such people should be settled as close as possible to their original homes and in model villages with amenities like electricity, safe water-supply, schools, roads, medical facilities, etc., and, further, that the lands given to them in exchange for lands to be submerged, be provided with irrigation facilities to the maximum extent possible.

Second phase of development

16·87 For the second phase, it has been recommended that the other dams proposed by Madhya Pradesh, viz., Barwaha, Burhner, Kolar and any others which they may wish to build, may be taken up according to priorities determined by them. Preference should, however, be given to Barwaha which would use regulated supplies from Punasa for generation of power and for irrigating important areas. The programme of medium and minor works in Madhya Pradesh should continue till completion.

Financing the Plan

16·88 The probable expenditure on development for each State has been indicated and it has been recommended that this should either be treated as a loan to the State concerned outside the State Plan or, alternatively, the Central Government may assume financial and technical responsibility for the key major components of the Plan to begin with.

The desirability of speedy implementation of a project, after it is sanctioned, has been stressed.

Levy of betterment fees and adjustment of water-rates, on the basis of cost of water supplied, have been proposed.

Fisheries

16·89 Fish culture in the reservoirs, to earn revenue and provide valuable food in short supply, has been recommended. A lot of research will have to be done to maximise the per acre yield of fish from reservoirs, which yield presently is miserably low.

Tourism

16·90 It has been suggested that large reservoirs, such as Punasa and Navagam, should be specially developed to provide attractions and facilities for tourists, who would then come there in large numbers.

Chapter XV

Organisational Set-up for Implementation

Madhya Pradesh

16·91 The Committee consider that projects in Madhya Pradesh, including Punasa, should be executed by that State. The State Government may consider setting up a Control Board and, preferably, also a Board of Consultants.

Gujarat

16·92 The Navagam dam and power project should be executed by Gujarat but to ensure common policy and overall technical and financial control, a Control Board on the Bhakra pattern may be constituted with representatives of all the participating States. This Board may appoint a Board of Consultants for advice on technical and other matters referred to it.

16·93 The Navagam canal should be the sole responsibility of the Gujarat Government who may consider the advisability of having a Control Board of their own with a representative of Rajasthan on it.

16·94 As regards the projects under the Mahi-Sabarmati complex, the State Governments of Gujarat and Rajasthan may consider the desirability of setting up a Control Board for their execution.

CHAPTER XVII

COMMITTEE'S RECOMMENDATIONS

Approach to the Master Plan

17·1 Regarding the Master Plan for the optimum and integrated development of the Narmada water resources, the Committee recommend that it should aim at—

(*i*) giving highest priority to National interest, while safeguarding, at the same time, the legitimate rights and needs of the States concerned ;

(*ii*) providing for maximum benefits in irrigation, power generation, flood control, navigation, fish culture, tourism, recreation, etc.;

(*iii*) extending irrigation to maximum area within physical limits of command, irrespective of State boundaries ;

(*iv*) extending irrigation to the arid areas of Great Rann of Kutch in Gujarat, and Barmer and Jalore in Rajasthan, both having a long common border with Pakistan, to enable sturdy peasants to settle permanently in such border lands and produce more food ; and

(*v*) reducing to the unavoidable minimum the waters going waste to the sea (Chapter XI—Para. 11·1).

Assessment of Areas to be irrigated and Water Requirements

17·2 The Narmada river at Navagam—where it debouches into the Gujarat plains—has a mean annual runoff of 36 million acre feet (Chapter V—Para. 5·26) against 32·8 MAF of the three Punjab rivers—the Sutlej, Beas and Ravi combined for irrigation of over 124 lakh acres. According to the Committee's assessment, this runoff of 36 MAF will fully provide for irrigation of 65 lakh acres in Madhya Pradesh, 45·81 lakh acres in Gujarat, 10,000 acres in Maharashtra and 1,00,000 acres in border areas of Rajasthan or a total of 111·91 lakh acres (Chapter VI—Paras. 6·28, 6·48, 6·49, 6·56), and after generation of all possible power, still leave 7·15 to 5·60 MAF (Chapter XII—Para. 12·10) going to the sea (Table 17·1).

TABLE 17·1

WATER ACCOUNT FOR VARIOUS PLAN PERIODS

Navagam FRL+500

	1975	1980	1985	1990	1995
	MAF	MAF	MAF	MAF	MAF
Consumptive use for irrigation ..	4·1	9·3	15·75	20·50	23·80
Utilisation for power ..	22·25	17·89	11·53	6·85	3·90
Evaporation losses ..	2·50	2·70	2·70	2·70	2·70
Water going to sea unutilised for irrigation or power.	7·15	6·11	6·02	5·95	5·60

17·3 After careful assessment, the Committee recommend the following areas for irrigation and water requirements (Table 17·2) in the various States, assuming a uniform delta of 2·4 ft. at canal head inclusive of reservoir losses (Chapter VII—Paras. 7·19 and 7·31) which figure has been derived from a study of realistic crop pattern, natural rainfall, drainage facilities and regeneration, use of subsoil water-table in areas in plains as a result of irrigation which will make available large volumes of water in subsoil reservoirs for use in lift irrigation by pumps or otherwise and thereby preventing waterlogging.

TABLE 17·2

Areas to be irrigated and Water Requirements

(Chapter VII—Para. 7·21)

PROJECT	MADHYA PRADESH		MAHA-RASHTRA		GUJARAT		RAJASTHAN		TOTAL	
	Irri. lakh acres	Water allowance MAF	Irri. lakh acrss	Water allowance MAF	Irri. lakh acres	Water allowance MAF	Irri. lakh acres	Water allowance MAF	Irri. lakh acres	Water allowance MAF
Major Projects ..	25·00	6·00	..	..	34·74	8·33	1·00	0·25	60·74	14·58
Medium Projects ..	32·00	7·68	0·10	0·10	..	..	..	..	32·10	7·78
Minor Projects ..	8·00	1·92	..	..	..	..	..	..	8·00	1·92
Great Rann of Kutch ..	..	..	..	..	4·50	1·08	..	..	4·50	1·08
*Mahi command transferred to Navagam canal.	..	..	..	..	6·57	1·58	..	..	6·57	1·58
Total ..	65·00	15·60	0·10	0·10	45·81	10·99	1·00	0·25	111·91	26·94
Deduct contribution of Heran and Orsang.	..	..	..	..	..	0·34	..	..	..	0·34
	..	..	..	..	..	10·65	..	..	..	26·60

* Equivalent water-supply of Mahi thus released shall be transferred for use in Rajasthan

The above is subject to the provision that Madhya Pradesh will have unrestricted use of water for their projects except in years of poor rainfall when sharing of stored supplies will have to be done (Chapter VII—Para. 7·13).

Sharing of water for irrigation in years of low runoff

The Committee recommend that sharing of water for irrigation between Madhya Pradesh and Gujarat should start when the total storage in all the Madhya Pradesh reservoirs including medium and minor and Navagam reservoir is less than 16·00 MAF on the 1st October. Madhya Pradesh will be entitled to three-fifths and Gujarat two-fifths.

If minor irrigation reservoirs and areas irrigated by them are excluded, then sharing will become necessary when the combined storage in all the medium and major reservoirs in Madhya Pradesh and Navagam reservoir is less than 14·5 MAF on the 1st October. This storage will be shared by Madhya Pradesh and Gujarat in the ratio of 4 : 3, respectively.

If the total storage is more than 14·5 MAF, but Navagam has less than 6·2 MAF of storage, then Madhya Pradesh reservoirs will have to make adequate releases to make up the deficit in Navagam reservoir (Chapter VII—Paras. 7·24 and 7·26).

Navagam Canal FSL+300

17·4 For irrigation of areas in Gujarat and Rajasthan, the Committee recommend FSL+300 (neither higher nor lower) for the Navagam canal (Chapter XII, Paras. 12·12 and 12·16).

Location of terminal storage reservoir, optimum level and installed capacity

17·5 The Committee recommend the Navagam site, at the downstream end of the 70 mile Hiranphal-Navagam gorge, as the best location for a terminal dam and reservoir.

The Committee further recommend FRL (Full Reservoir Level) of+500 as the optimum for a reservoir at the Navagam site.

The Committee also recommend that the installed capacity at the river bed power station and the canal power station should be 1000 MW and 240 MW, respectively with one standby unit in each.

These recommendations are based on considerations of economics, power development, flood control and reducing to the minimum wastage of water to the sea (Chapter XII, Paras. 12·7, 12·14, 12·15 and 12·16).

Implementation of Projects in Madhya Pradesh

17·6 The Committee recommend that all dams and other works located in Madhya Pradesh should be the exclusive concern of and be executed by that State (Chapter XV, Para. 15·8).

Implementation of Navagam Project

17·7 In respect of Navagam dam, power plant and appurtenant works, the Committee recommend that these should be treated as a joint project. These should be executed by the Government of Gujarat under the overall financial and technical control of a Control Board which should have representatives of the three State Governments, constituted generally on the Bhakra model. The Control Board should be assisted by a Board of Consultants as for the Bhakra project (Chapter XV, Paras. 15·9, 15·10, 15·11 and 15·12).

The construction of Navagam canal and any power development on this canal or river system in Gujarat, will be the responsibility of the Gujarat Government. The latter may set up a suitable Control Board for the purpose, and may have a representative of Rajasthan for only the cana' portion of the project (Chapter XV, Para. 15·13).

Sharing of Benefits

The Committee further recommend that the costs and benefits of the project be shared by the participating Governments in the proportions set forth below—the cost of irrigation part being wholly borne by the Gujarat State (Chapter XIII Para. 13·6 and Annexure XII-4A).

The Committee have proceeded on the assumption that Madhya Pradesh should get as much power from Navagam as it would have got if a dam with FRL+465 had been constructed at Hiranphal, and that the other two States should share the balance equally.

Calculated on this basis, the shares for Navagam+465 for the mean year 1985 would be—(Chapter XIII, Para. 13·6).

Madhya Pradesh		Gujarat		Maharashtra
1·64	:	1	:	1

Almost the entire submersion of culturable areas will be in Madhya Pradesh. Although compensation under the Land Acquisition Act would be paid by the project both for culturable and other areas, the resettlement and rehabilitation of the persons displaced will pose a major human problem for that State.

The Committee, therefore, recommend that the ratio of sharing for the mean year, as well as for all other years, should be Madhya Pradesh (2), Maharashtra (1) and Gujarat (1) for Navagam FRL+465.

The Committee further recommend sharing for this and higher levels of Navagam reservoir as given in Table 17·3 (Chapter XIII, Para. 13·6).

TABLE 17·3

Proportionate shares of power for different FRLs of Navagam Reservoir

FRL of Navagam reservoir	Culturable area submerged			Proportionate share of		
	Madhya Pradesh	Maharashtra	Gujarat	Madhya Pradesh	Maharashtra	Gujarat
	Acres	Acres	Acres			
+465	25,600	1,900	2,500	2·00	1	1
+480	52,500	1,950	2,560	2·15	1	1
+490	73,500	2,000	2,600	2·30	1	1
+500	94,500	2,050	2,630	2·50	1	1

The consequent share of power of each State for different reservoir levels and different years is given in Table 17·4.

TABLE 17·4

Shares of power for different FRLs of Navagam and different stages of development

FRL of Navagam	Share of Madhya Pradesh					Share of Maharashtra					Share of Gujarat				
	1975	1980	1985	1990	1995	1975	1980	1985	1990	1995	1975	1980	1985	1990	1995
+500	586	632	527	386	283	234	254	212	155	114	234	254	212	155	114
+490	..	..	473	..	..	..	..	205	..	..	..	..	205	..	..
+480	..	..	434	..	..	..	..	201	..	..	..	..	201	..	..
+465	521	531	388	269	185	261	266	194	135	92	261	266	194	135	92

NOTE—When, with full utilisation for irrigation, the quantity of power generated goes down, the hydro-power station can be used as a peaking station with load factor of 30 per cent or lower, thus making full use of the installed capacity.

The Committee also recommend that power surplus to the requirement of any of the States should be sold to other participating States in proportion to their shares specified in Table 17·3 (Chapter XIII, Para. 13·9).

Gujarat will be free to generate power on the canal and river system in the State at their own expense. The development of power at the head regulator of the canal will be in the common pool. (Chapter XIII, Para. 13·11).

Allocation of cost between irrigation and power

17·8 The allocation of costs between irrigation and power has been based on the mean year 1985. The allocation to power will, therefore, remain the same for all years for the same FRL of Navagam reservoir. For other FRLs of Navagam reservoir, this allocation will vary on the basis mentioned above. (Chapter XIII, Para. 13·2).

Sharing of Cost

17·9 Shares of cost will, accordingly, be as given in Table 17·5.

TABLE 17·5

Sharing of power portion of cost of Navagam dam, power plant and appurtenant works for different FRLs

FRL of Navagam	Total cost of power portion	Share of		
		Madhya Pradesh	Maharashtra	Gujarat
			Rupees crores	
+465	119	59·5	29·75	29·75
+480	132·3	68·5	31·90	31·90
+490	140·5	75·3	32·60	32·60
+500	147	81·6	32·70	32·70

The above costs are inclusive of the amounts mentioned in Paras. 17·10 and 17·11 below.

400 KV Transmission link between Navagam and Barwaha

17·10 The Committee recommend the construction of 400 KV transmission link between Navagam and Barwaha power stations. Cost of the link up to Hiranphal only, with sub-station at Hiranphal, is estimated at Rs. 8 crores, which will be charged to the power part of the Navagam project (Chapter XIII, Para. 13·6).

Allowance for regulated releases from Punasa Reservoir

17·11 Navagam project will be utilising regulated releases from the Punasa project upstream. The Committee do not accept the principle that part of the cost of upper riparian project be allocated to the projects down below. However, under the special circumstances of Navagam project, the Committee recommend charging a fixed sum of Rs. 13 crores, irrespective of the actual cost of the Punasa dam, to Navagam project on account of this. Out of this, Rs. 8 crores will be chargeable to the power part of Navagam project and Rs. 5 crores to the irrigation part (Chapter XIII, Para. 13·7).

Cost of power generation

17·12 Cost of power generation at Navagam for FRLs+465 as well as +500 for the different years is given in Table 17·6 (Annexure XIII-4, B-1 and B-2).

TABLE 17·6

Cost of power generation at Navagam

	1975		1980		1985		1990		1995	
	Rs. per KW	Paise per kwh	Rs. per KW	Paise per kwh	Rs. per KW	Paise per kwh	Rs. per KW	Paise per kwh	Rs. per KW	Paise per kwh
Navagam+500 Capital cost Rs. 147 crores	1,393	1·73	1,290	1·98	1,545	2·65	2,110	3·61	2,880	4·93
Corresponding to sum at charge.	1,380	1·43	800	1·28	438	1·14	51	0·97	Nil	1·19
Navagam+465 Capital cost Rs. 119 crores	1,140	1·73	1,120	1·91	1,533	2·63	2,210	3·75	3,230	5·52
Corresponding to sum at charge.	1,090	1·43	621	1·16	308	1·01	Nil	0·86	Nil	1·26

Navigation

17·13 The cost of providing navigation facilities in the form of lift weirs, locks, connecting channels, raising of bridges, etc., up to Bargi reservoir has been very roughly estimated between Rs. 50 and 60 crores.

The Committee recommend that the designs of navigation works should be taken up simultaneously with the design of canals, regulators, dams, etc., so that both works can be taken up for construction at the same time.

It would be desirable to provide navigation facilities as soon as the inland waterways become available for navigation.

The Committee further recommend that the Central Government (Ministry of Transport) should assume full responsibility for the capital cost involved in the construction of structures necessary to provide navigation facilities and share the revenues therefrom with the concerned States on an agreed basis (Chapter IX, Paras. 9·10 and 9·11).

Phasing of the Master Plan

17·14 The Committee recommend for implementation in full, the Master Plan for the optimum and integrated development of Narmada water resources, consisting broadly of 13 major irrigation and power projects, 12 of which are in Madhya Pradesh and one in Gujarat (Chapter XIV, Para. 14·1). In addition Madhya Pradesh would be free to take up medium and minor irrigation projects to the extent resources in staff, funds and material permit.

17·15 In the phasing given for the implementation of this Plan, the Committee have presumed that preliminary works on phase I of the Plan will be authorised in 1965-66.

The First Phase

17·16 The Committee further recommend that besides expediting the projects already sanctioned, *viz.*, Tawa and Barna, the Madhya Pradesh Government should take up Punasa (the key project of the State) and Bargi projects; and Gujarat should take up Navagam project in the first phase of development.

The canal system under Navagam project should also be started at an early date to enable Gujarat to take full advantage of the larger supplies (especially for reclamation purposes) which would be available in the Narmada in earlier years of irrigation development and to carry waters to the Great Rann of Kutch and Rajasthan areas bordering on Pakistan (Chapter XIV, Para. 14 11).

The Second and subsequent phases

17·17 In the second and subsequent phases, the rest of the dams in Madhya Pradesh, viz., Barwaha, Burhner and Kolar and any other project which Madhya Pradesh Government may like to take up for irrigation or power or both, may be built, subject to availability of resources, etc.

The Committee recommend that preference should be given to the construction of Barwaha dam to utilise the regulated supplies from Punasa (Chapter XIV, Para. 14·22).

Programme of Irrigation and Power development

17·18 In drawing up the phased programme of basinwise development, the Committee have kept in view the acute shortage of food, the all-round power shortage, the necessity for raising additional financial resources and the reported decision of the Planning Commission to make massive allocation for irrigation and power in the Fifth, Sixth and subsequent plans.

Irrigation is essential for producing more food but, in the present context of low water rates, irrigation projects are unproductive and an increasing burden on the State exchequer.

Power projects, on the other hand, raise substantial additional financial resources apart from stimulating industrial development.

The Committee recommend—

(*a*) that question of raising water rates and imposition of betterment levy be given serious consideration to enable irrigation projects to become self-supporting;

(*b*) that power units be installed to ultimate maximum capacity as soon as each dam gets completed, so that maximum power can be generated and maximum resources raised from the very start of operation of the project, as there will be large quantities of water otherwise going waste to the sea in the early stages of irrigation development.

The load forecasts of the three States confirm that power will be used up to any extent as soon as generated.

Waterlogging and Drainage

17·19 With the introduction of large-scale irrigation in Madhya Pradesh and Gujarat, substantial quantities of water will be stored up in sub-soil reservoirs, which will raise sub-soil water level to varying depths below the surface, resulting in waterlogging of low lying areas. It would be necessary to keep this water level in the areas in plains within safe limits for crop production.

The Committee recommend that the natural drainages of the commanded area should be taken care of simultaneously with the introduction of large-scale irrigation and that supplemental irrigation by pumping should also be undertaken simultaneously which, besides controlling the rise of subsoil water level, will also help to conserve supplies in surface reservoirs for use in extending irrigation and generating power (Chapter VII, Para. 7·31).

Necessity for investigations

17·20 The Committee would like to stress the necessity for immediate start on large-scale investigations under a phased programme, so as to be able to establish the feasibility, priority and economics of any project well in advance of authorisation for its implementation. These will also provide a wide choice for selection of projects.

The number of discharge sites on the Narmada and rain gauges of Indian Meteorological Department standard in the free catchment below Punasa are few. The Committee recommend that their numbers should be adequately increased (Chapter V, Para. 5·43).

Training of personnel

17·21 The Committee recommend that training of personnel for the implementation of the various phases of the Master Plan should be given immediate consideration. This training can well be arranged on major projects already under construction in the country, such as the Beas, Yamuna, Ramganga, Sabarigiri, Rana Pratap Sagar, Sharavathy and several projects in Madras and other States.

Resettlement and Rehabilitation

17·22 The resettlement and rehabilitation of persons displaced as a result of the construction of projects, particularly those included in the first phase, will present a major human problem. It would be necessary to find alternative lands for their resettlement.

The Committee recommend that the best solution would be to reclaim waste lands on the fringes of the reservoirs and provide them with perennial irrigation from medium and minor works constructed on the minor streams or from the reservoirs themselves. The Committee also recommend that the lands on which the oustees are to be resettled should be selected, made ready and allotted well before their original lands are submerged. Work on resettlement programme should, therefore, start simultaneously with that on the dams and with equal urgency. Efforts should also be made to resettle the inhabitants of a group of villages in contiguous areas to preserve communal life (Chapter XIV, Paras. 14·12 to 14·20).

Cost of the Plan

17·23 The total cost of all the projects contemplated under the Master Plan has been estimated at Rs. 1,050 crores to be spent in the course of thirty years from start of construction for full development (Chapter XIV, Para. 14·23).

Financing of the Plan

17·24 The probable expenditure on development has been estimated roughly at Rs. 643 crores for Madhya Pradesh and Rs. 300 crores for Gujarat.

The Committee recommend that this should either be treated as a loan to the State concerned, outside the State plan or, alternatively, the Government of India may assume financial and technical responsibility for the key major components of the Plan to begin with.

The Committee stress the desirability of speedy implementation of a project once it is sanctioned, so that construction costs can be kept at the minimum and substantial financial resources can be raised from the very start of operation of the project, particularly, the power part (Chapter XIV, Para. 14·24).

Fish culture

17·25 The Committee recommend the development of fish culture on a large scale in the reservoirs with a view to earning revenues and providing valuable nutritious foods which are in short supply.

The per acre yield of fish from reservoirs is miserably low at present and the Committee recommend that concentrated research be undertaken to raise this yield manifold. As an illustration, the Chilka Lake in Orissa yields 75 lbs. of fish to the acre, and the Hirakud reservoir only 0·5 lb. to the acre, whereas in a number of highly developed fish ponds abroad, the yields are as high as 2,000 lbs. and more per acre (Chapter XIV, Para. 14·25).

Tourism

17·26 The Committee recommend that large reservoirs, such as Punasa and Navagam, should be specially developed to provide attractions and facilities for tourists who would visit the sites in large numbers (Chapter XIV, Para. 14·26).

Integrated development of the Mahi and Sabarmati waters

17·27 The Committee recommend that the optimum development of the Mahi and Sabarmati rivers for irrigation and power should be undertaken in integration with the Narmada development. For the optimum utilisation of the water resources of the Mahi, it would be necessary to construct four dams, viz., Banswara, Baneshwar and Kadana on the Mahi, and Anas on the tributary by that name. Of these, Banswara and Kadana projects are likely to be sanctioned shortly by the Planning Commission. The Committee recommend that investigations for the remaining two projects, namely, Baneshwar and Anas, should be completed as early as possible and the projects finalised (Chapter VIII, Para. 8·15).

As indicated in Table 17·2 above, it is proposed to transfer the area under Mahi command in Gujarat to Navagam canal and to transfer the corresponding Mahi waters to irrigate higher areas in Rajasthan which cannot be commanded by Navagam canal.

The Committee recommend that the cost of the dams and works chargeable to power and irrigation, respectively, on the Mahi system and the benefits therefrom should be shared in the ratio of 2 for Rajasthan and one for Gujarat subject to such marginal adjustments as may be mutually agreed upon (Chapter VIII, Para. 8·30).

The Committee further recommend that the State Governments of Gujarat and Rajasthan should consider the question of setting up a Control Board for the execution of projects under the Mahi-Sabarmati complex (Chapter XV, Para. 15·14).

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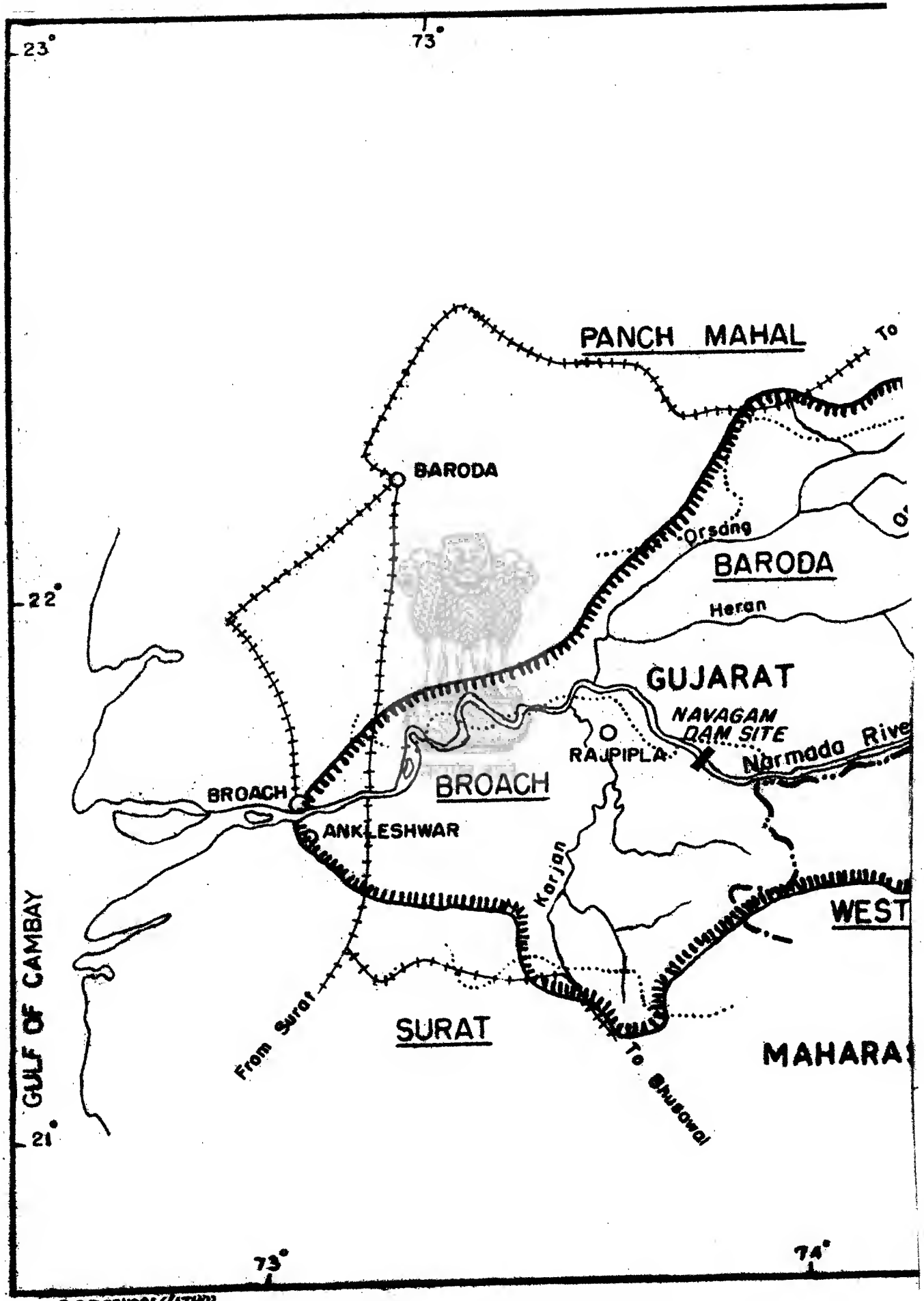

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INDEX MAP OF NARMADA B

SHOWING POLITICAL DIVISIONS

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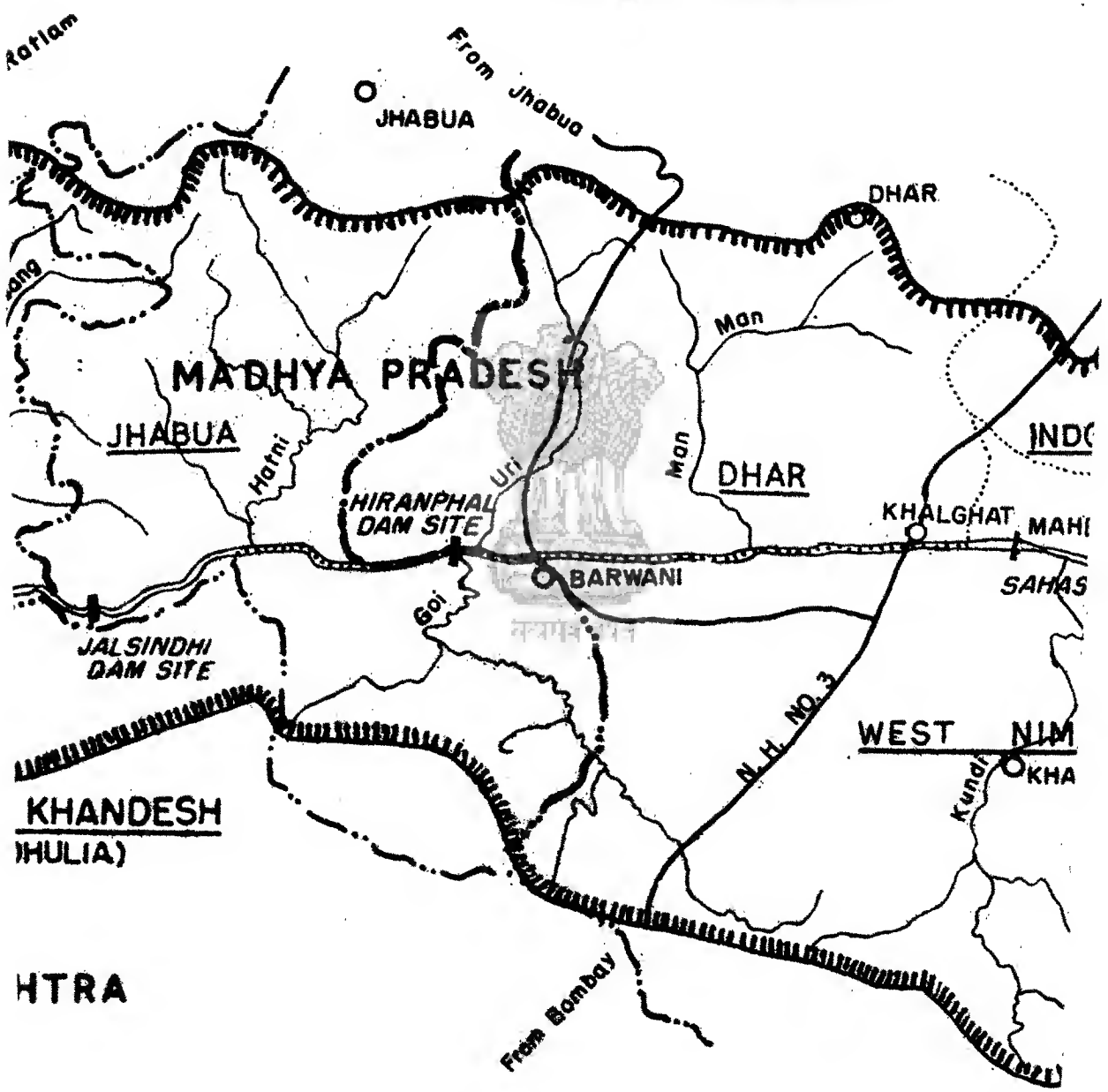

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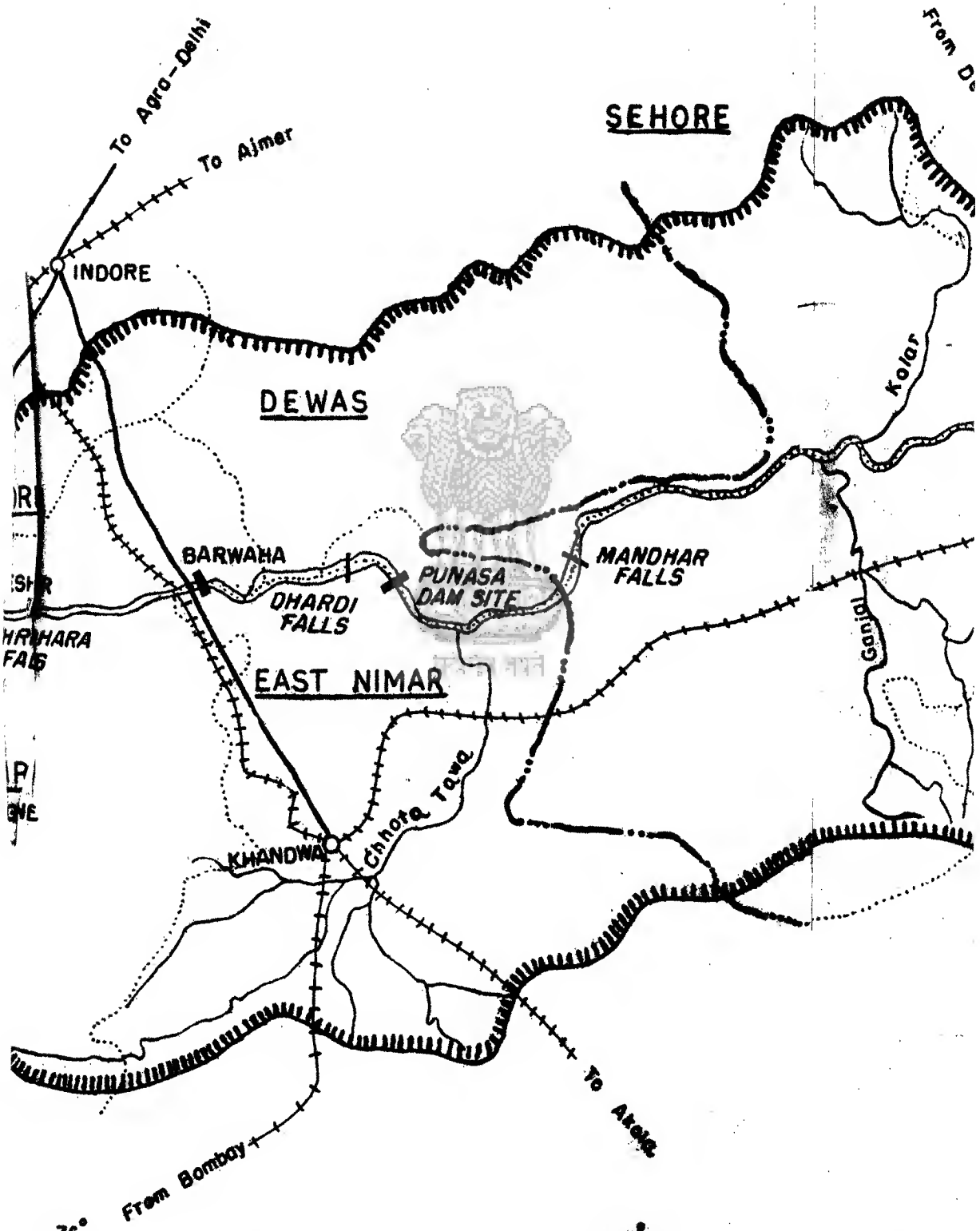
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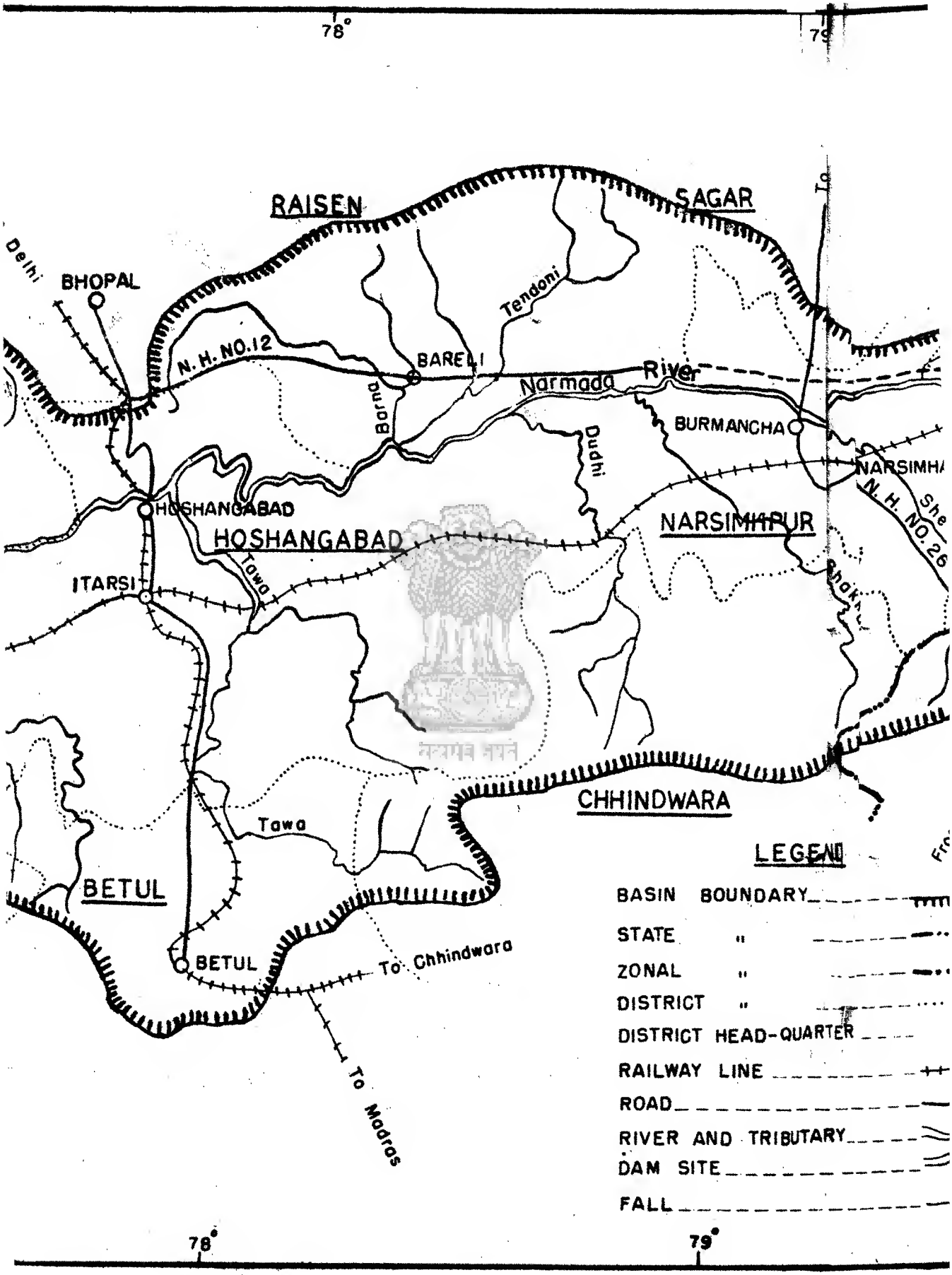
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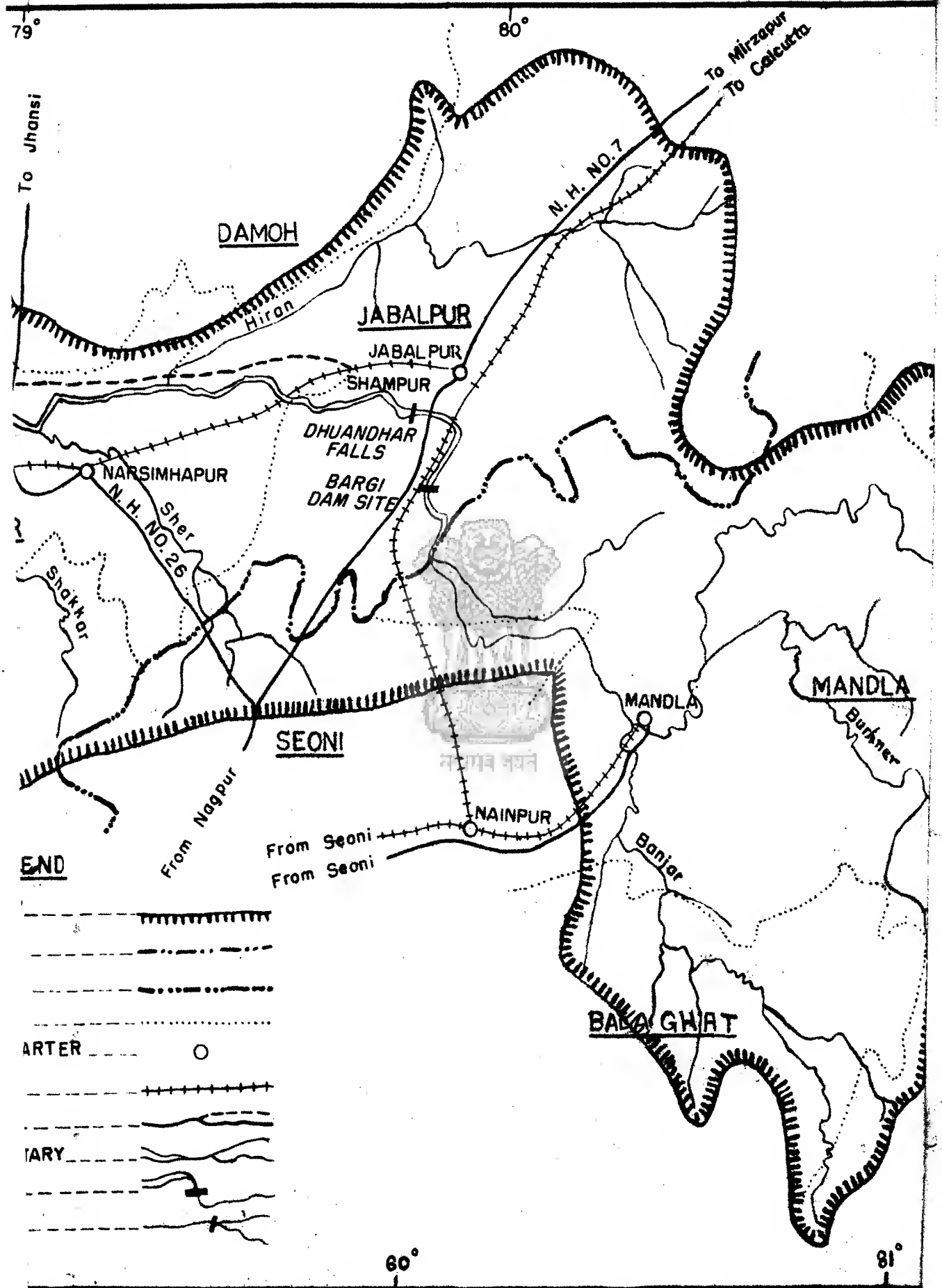
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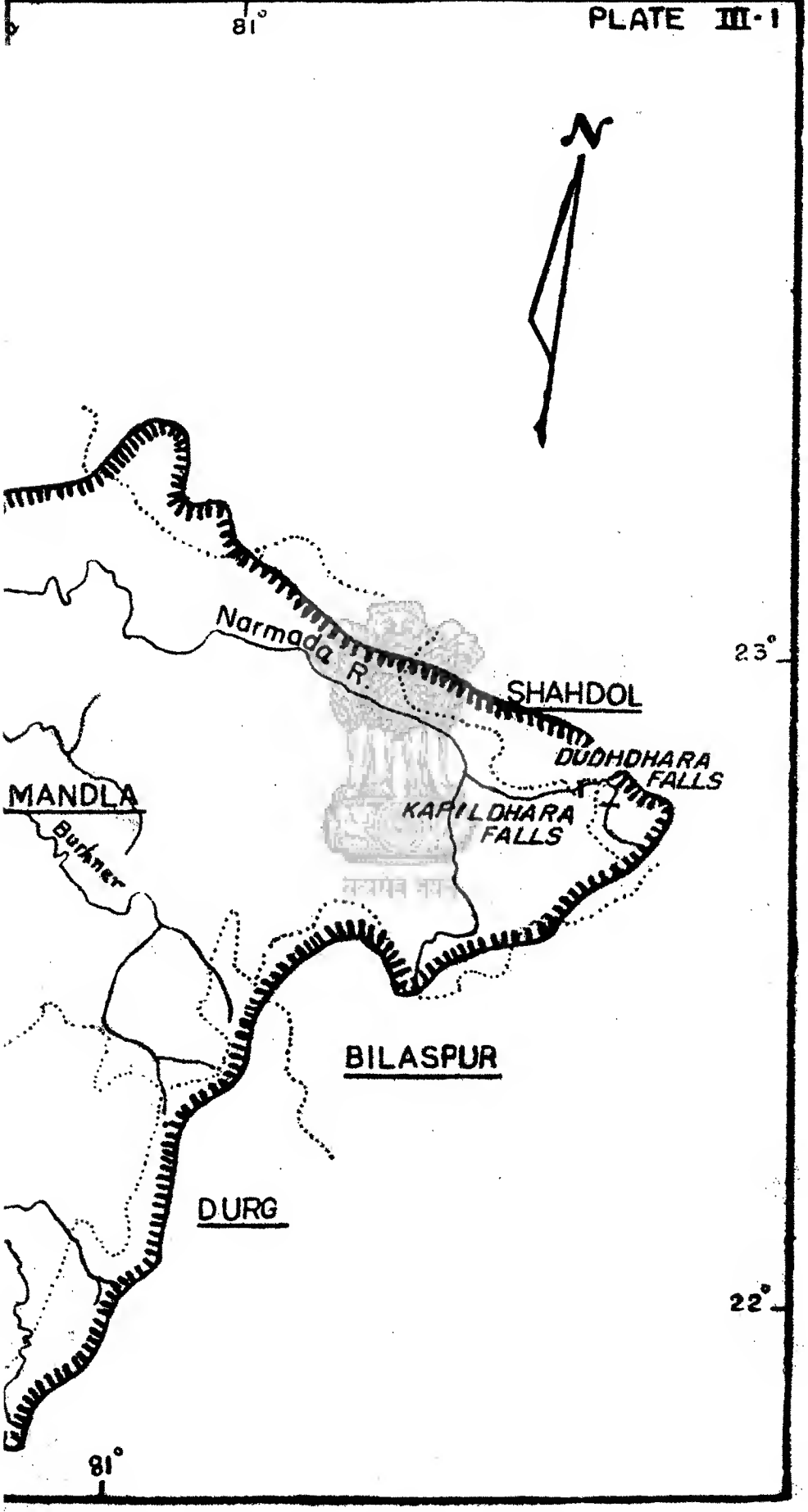
PLATE III-1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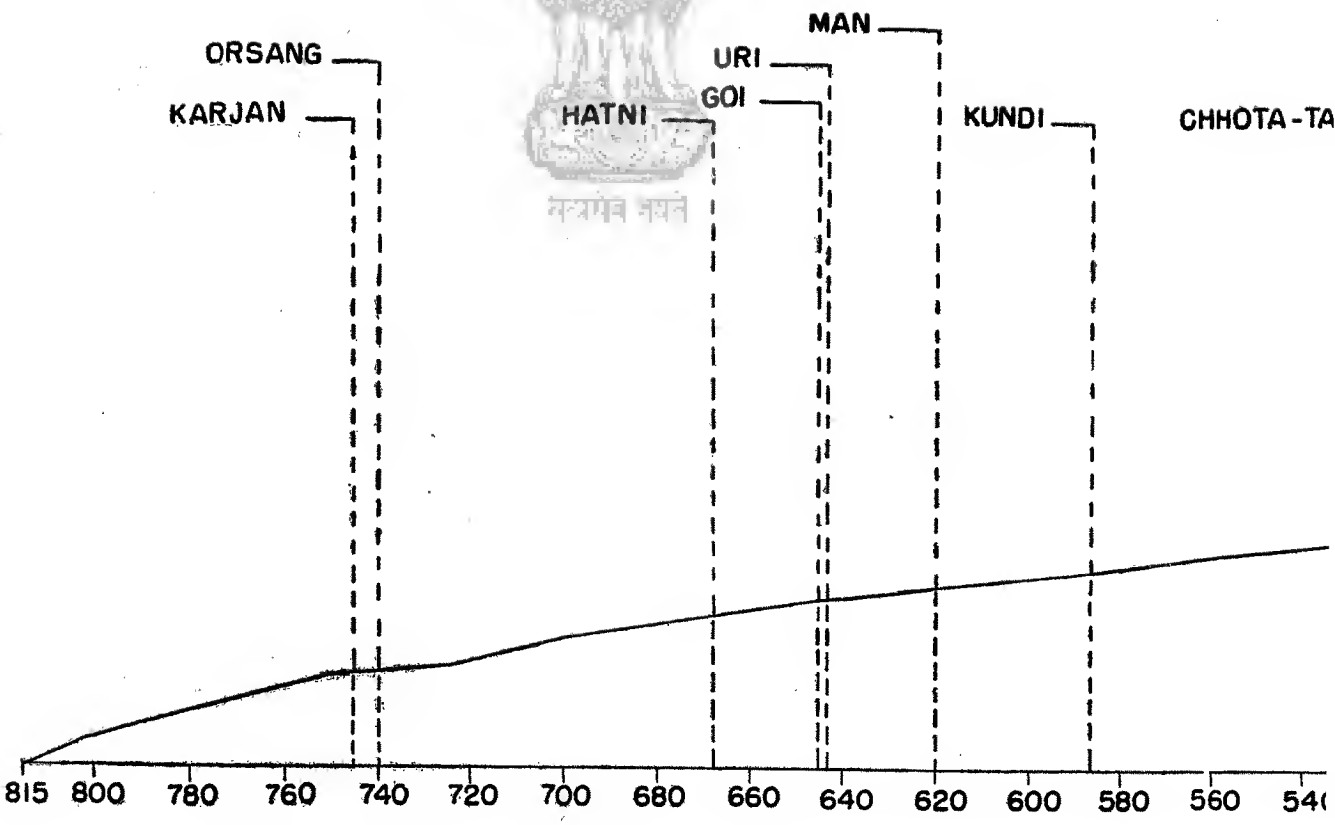
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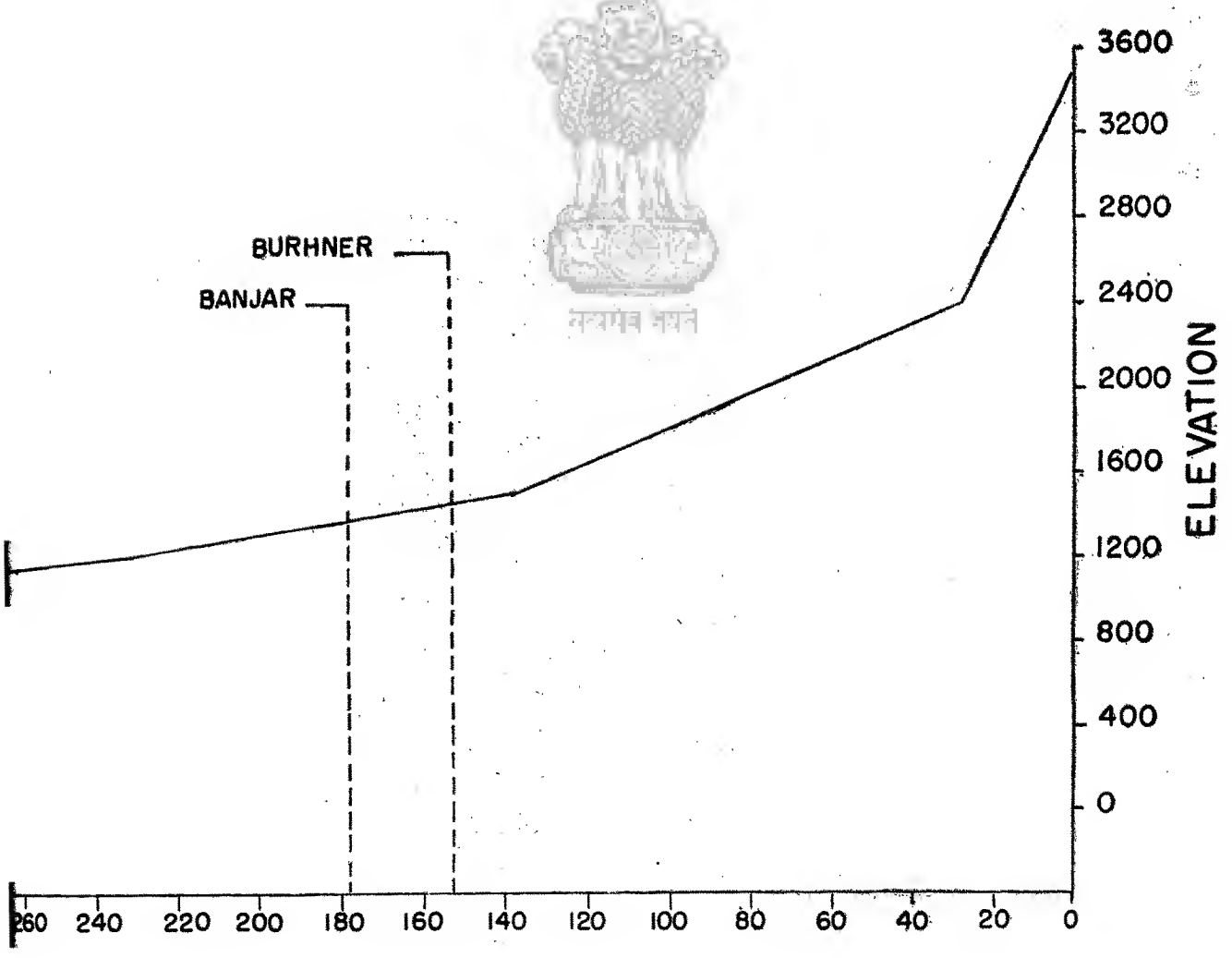
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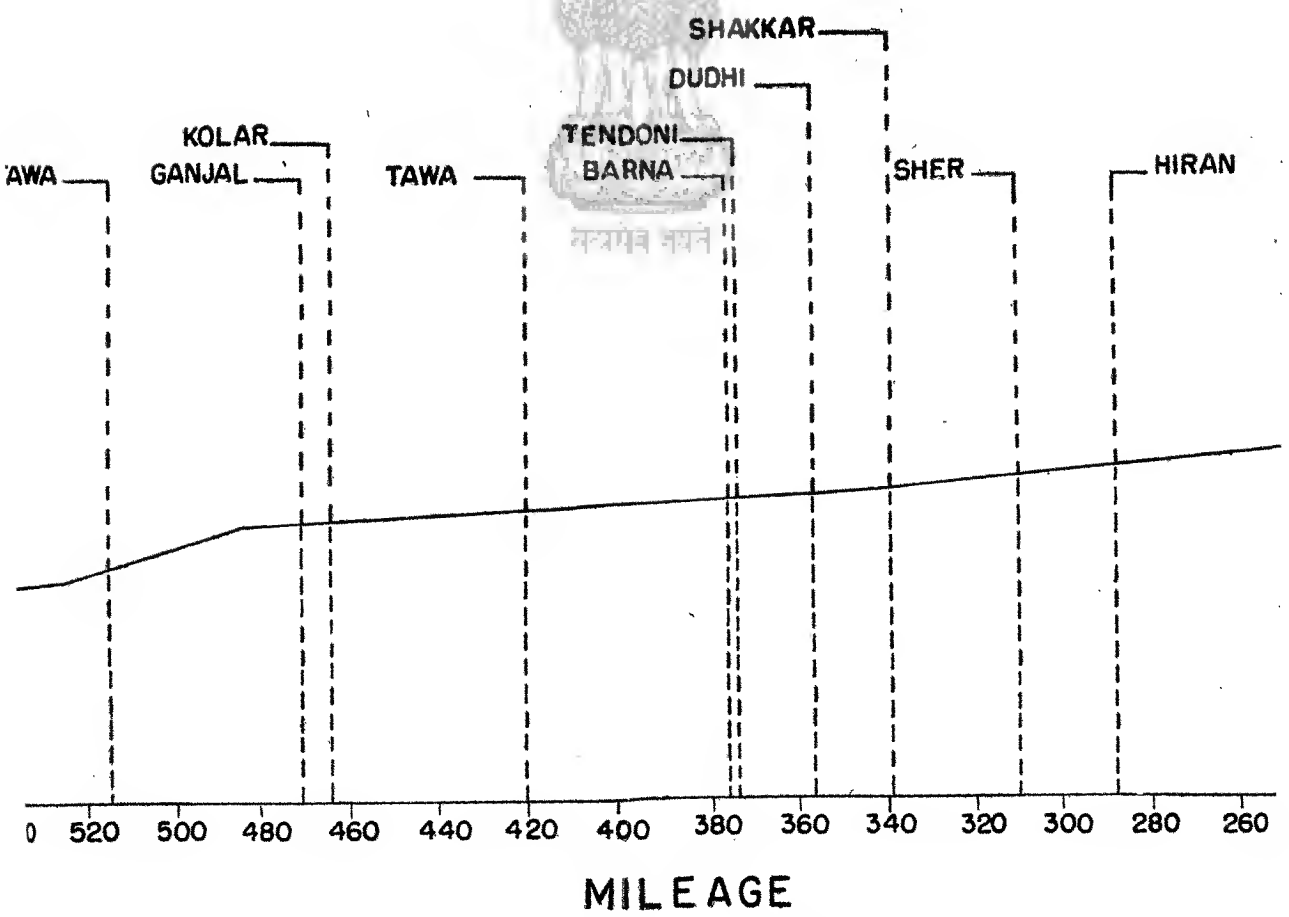
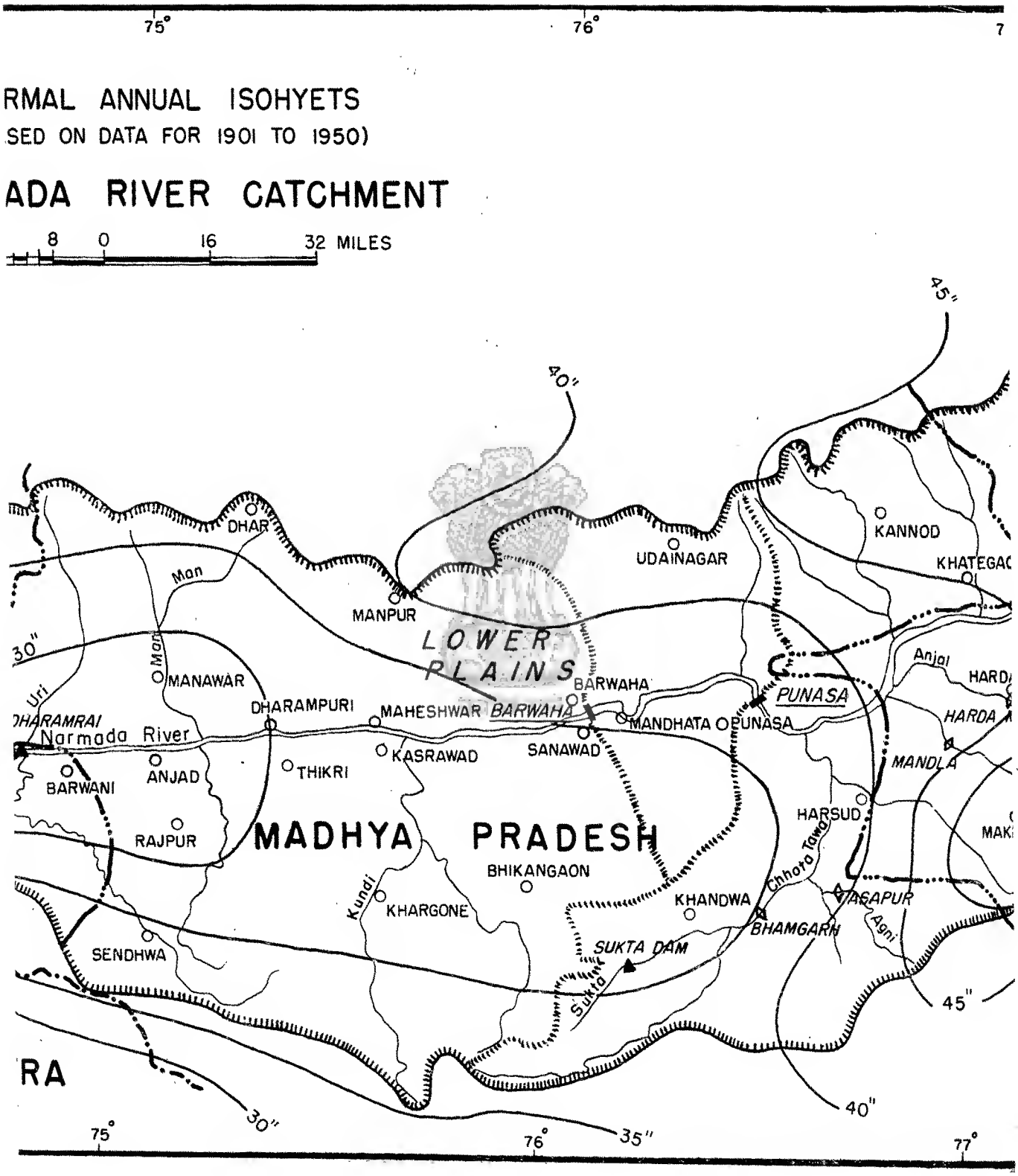
SECTION OF NARMADA RIVER

SCALE :— HOR.— 1"= 40 MILES
VER.— 1"= 800 FEET

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PUNASA
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SANAWAD
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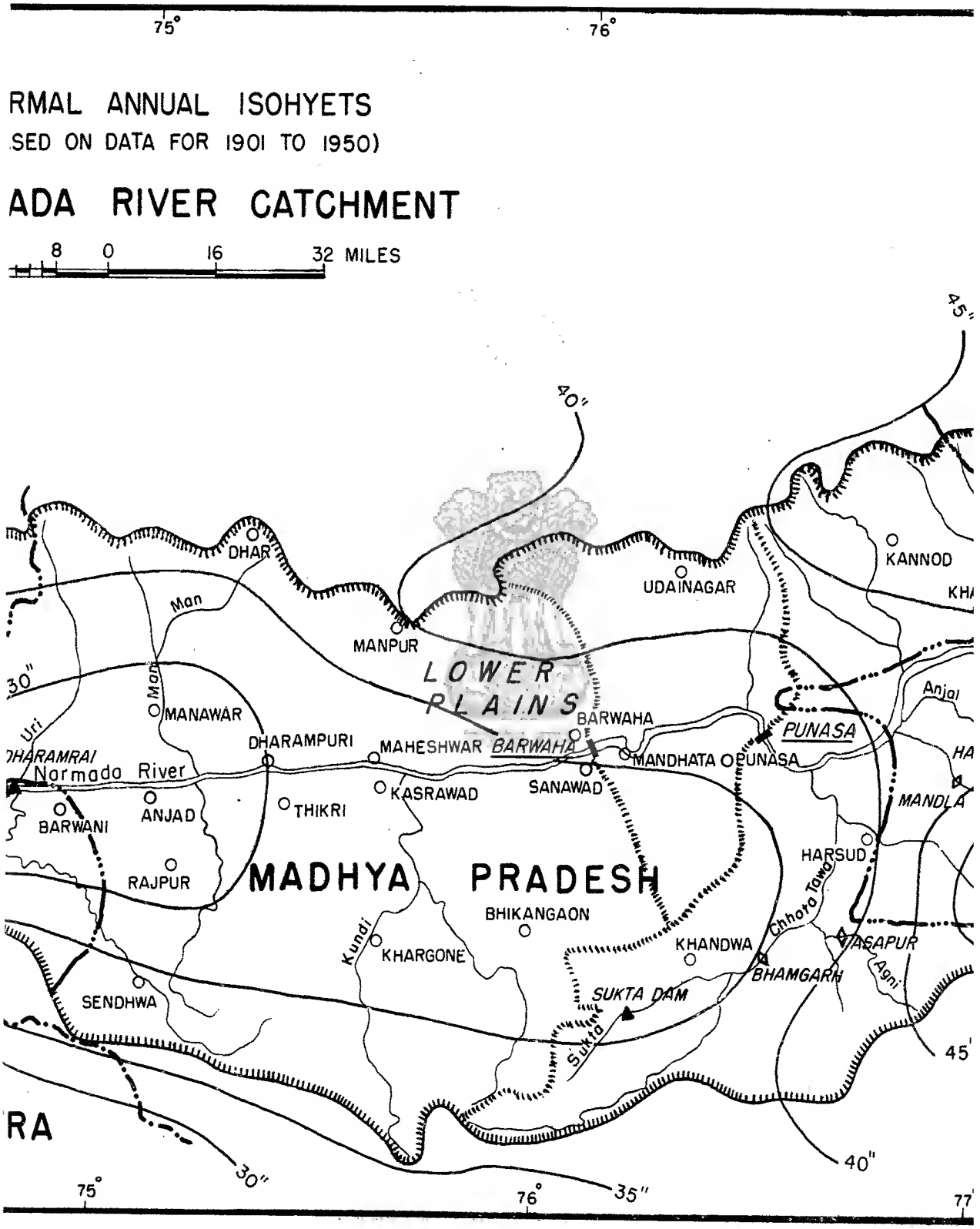
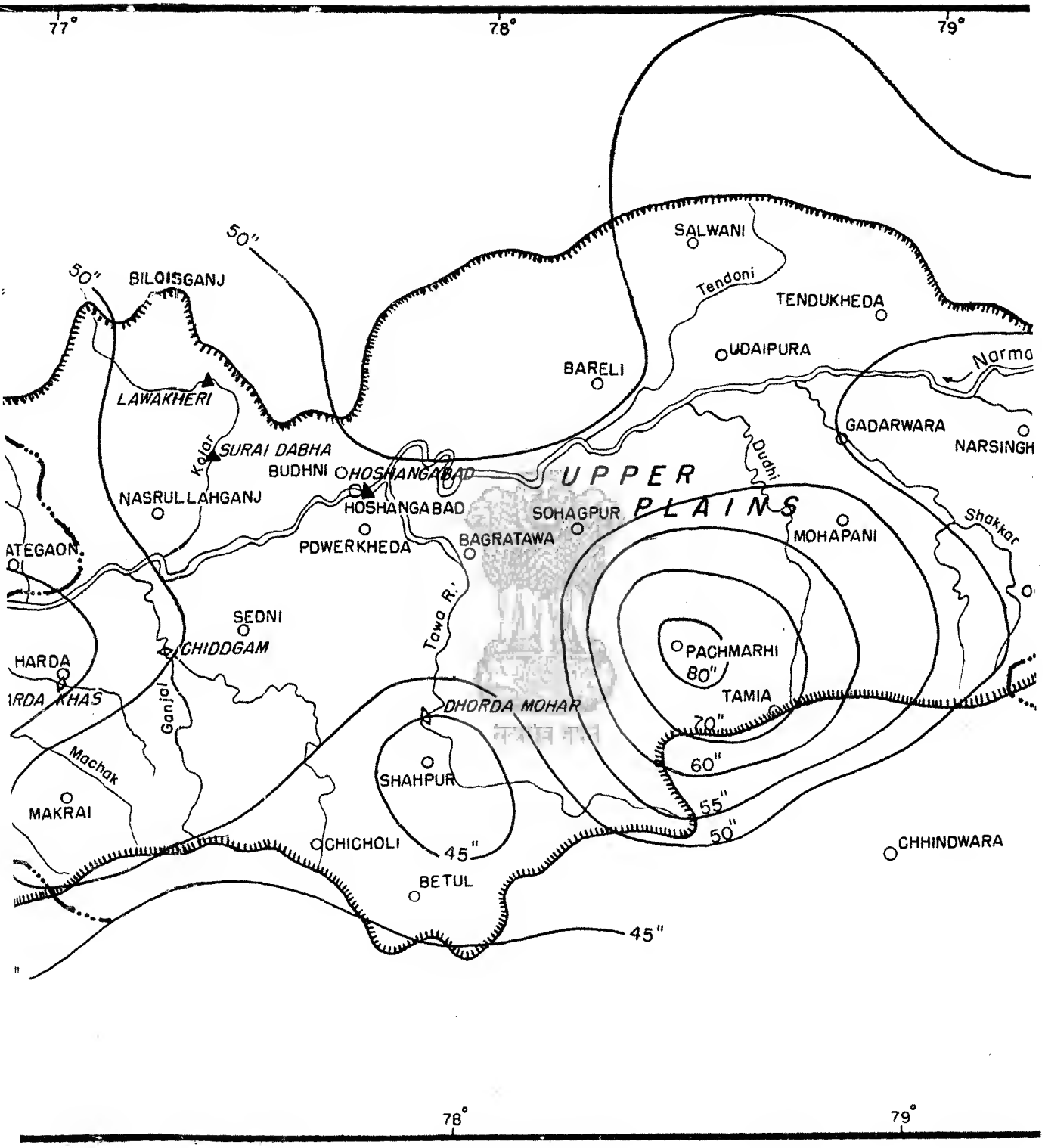
RAJPUR
MADHYA PRADESH
BHIKANGAON
Kundi
KHARGONE
KHANDWA
Chhoto Tawa
BHAMGARH
Agni
SENDHWA
SUKTA DAM
Sukta
RA
35"
77°


75°
76°
RMAL ANNUAL ISOHYETS
SED ON DATA FOR 1901 TO 1950)
ADA RIVER CATCHMENT
8 0 16 32 MILES
45"
40"
30"
DHAR
Man
MANPUR
UDAINAGAR
KANNOD
KHA
LOWER PLAINS
Anjal
MANAWAR
Uri
BARWAHA
PUNASA
DHARAMRAI
DHARAMPURI
MAHESHWAR
BARWAHA
MANDHATA
PUNASA
HA
Narmada River
KASRAWAD
SANAWAD
MANDLA
BARWANI
ANJAD
THIKRI
HARSUD
RAJPUR
MADHYA PRADESH
BHIKANGAON
Chhota Tawa
Kundi
KHARGONE
KHANDWA
ASAPUR
Agni
BHAMGARH
SUKTA DAM
SENDHWA
Sukta
45'
RA
40"
30"
35"
75°
76°
77'


77°
78°
79°
50"
50"
BILOISGANJ
SALWANI
Tendoni
TENDUKHEDA
UDAIPURA
BARELI
Narma
LAWAKHERI
Kolar
SURAI DABHA
BUDHNI
HOSHANGABAD
NASRULLAHGANJ
HOSHANGABAD
UPPER
PLAINS
Dudhi
GADARWARA
NARSINGH
SOHAGPUR
MOHAPANI
Shakkar
PDWERKHEDA
BAGRATAWA
ATEGAON
SEDNI
Towa R.
CHIDDGAM
PACHMARHI
80"
HARDA
TAMIA
70"
DHORDA MOHAR
Ganjal
60"
Machak
SHAHPUR
55"
MAKRAI
50"
CHHINDWARA
CHICHOLI
45"
BETUL
45"
78°
79°

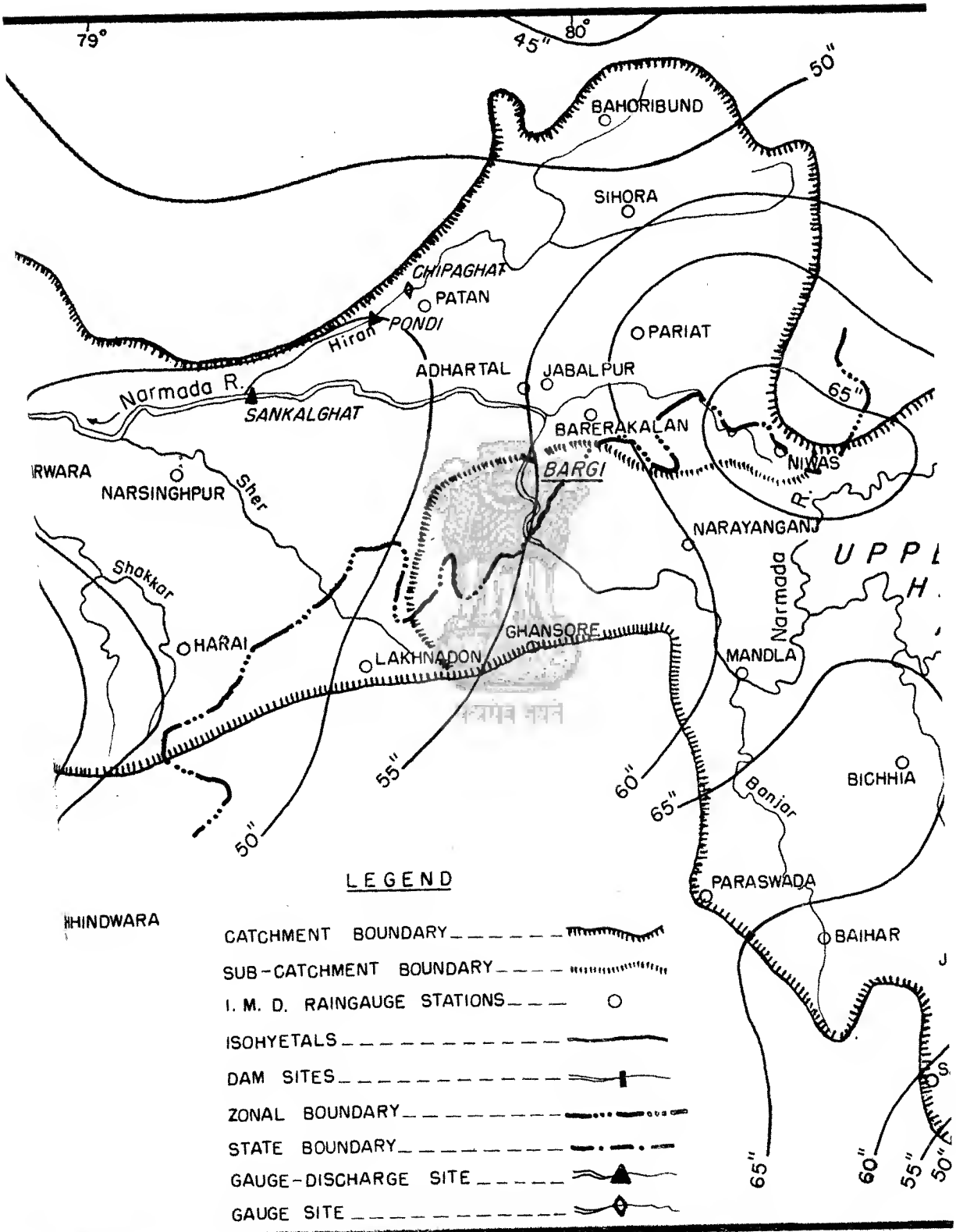
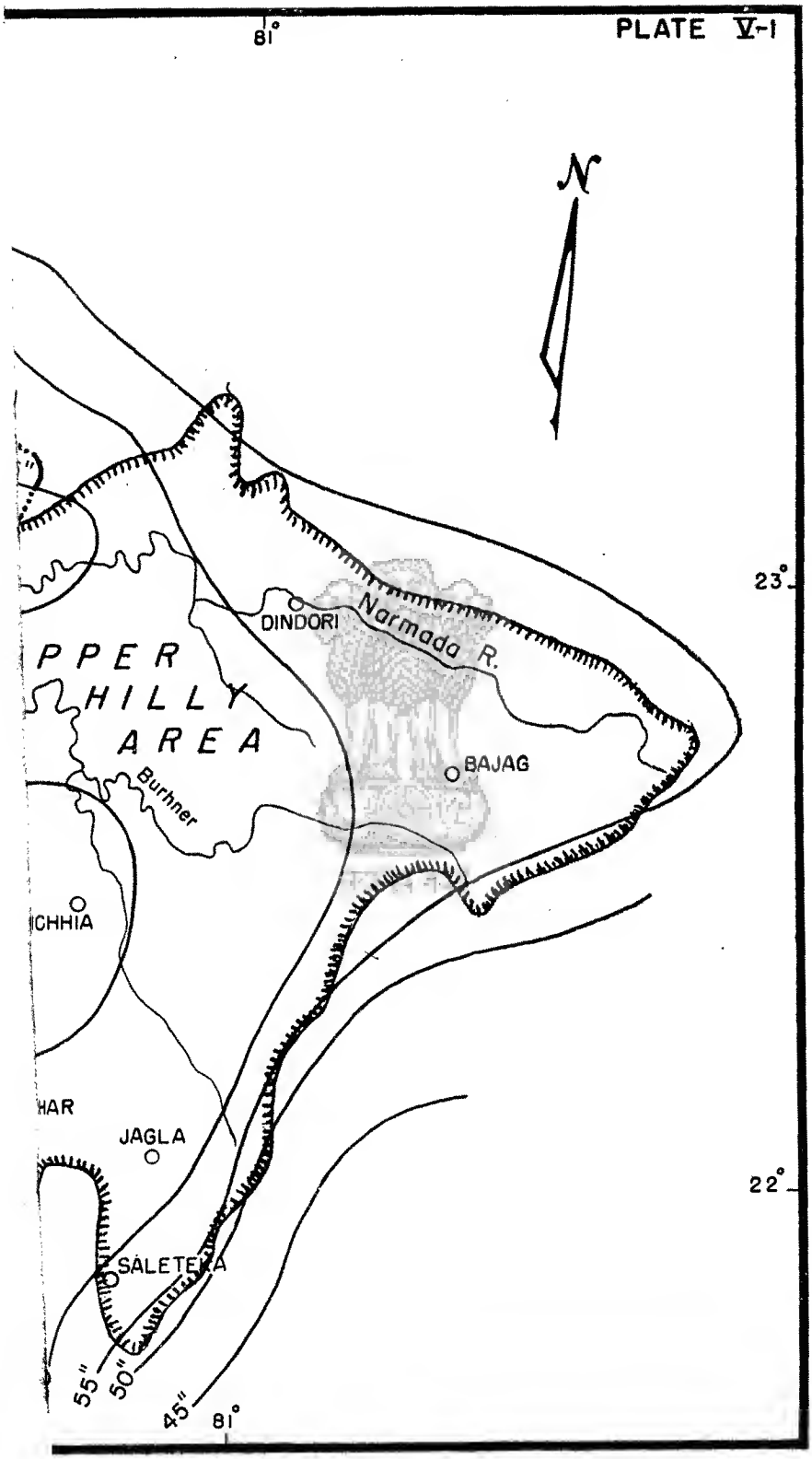
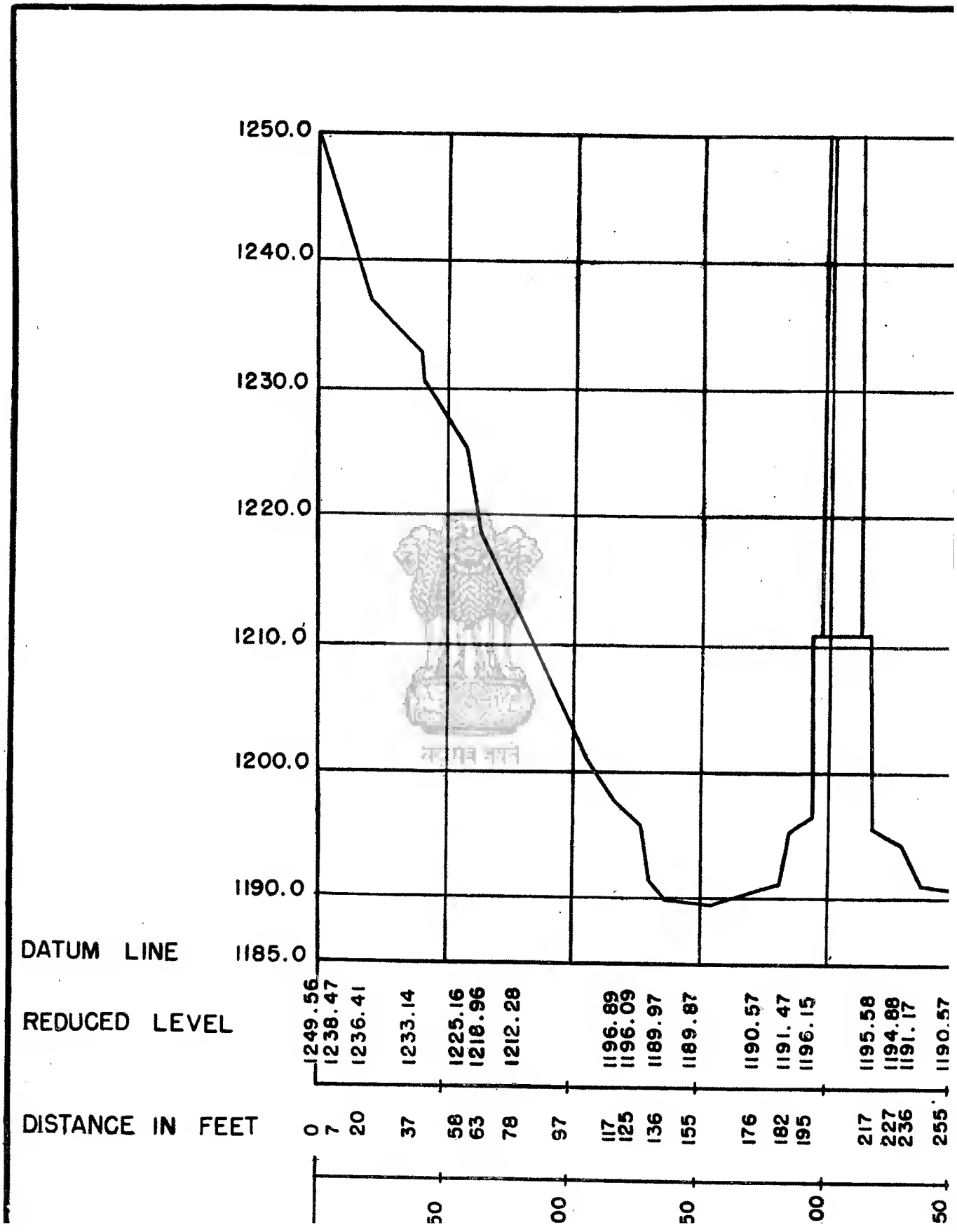
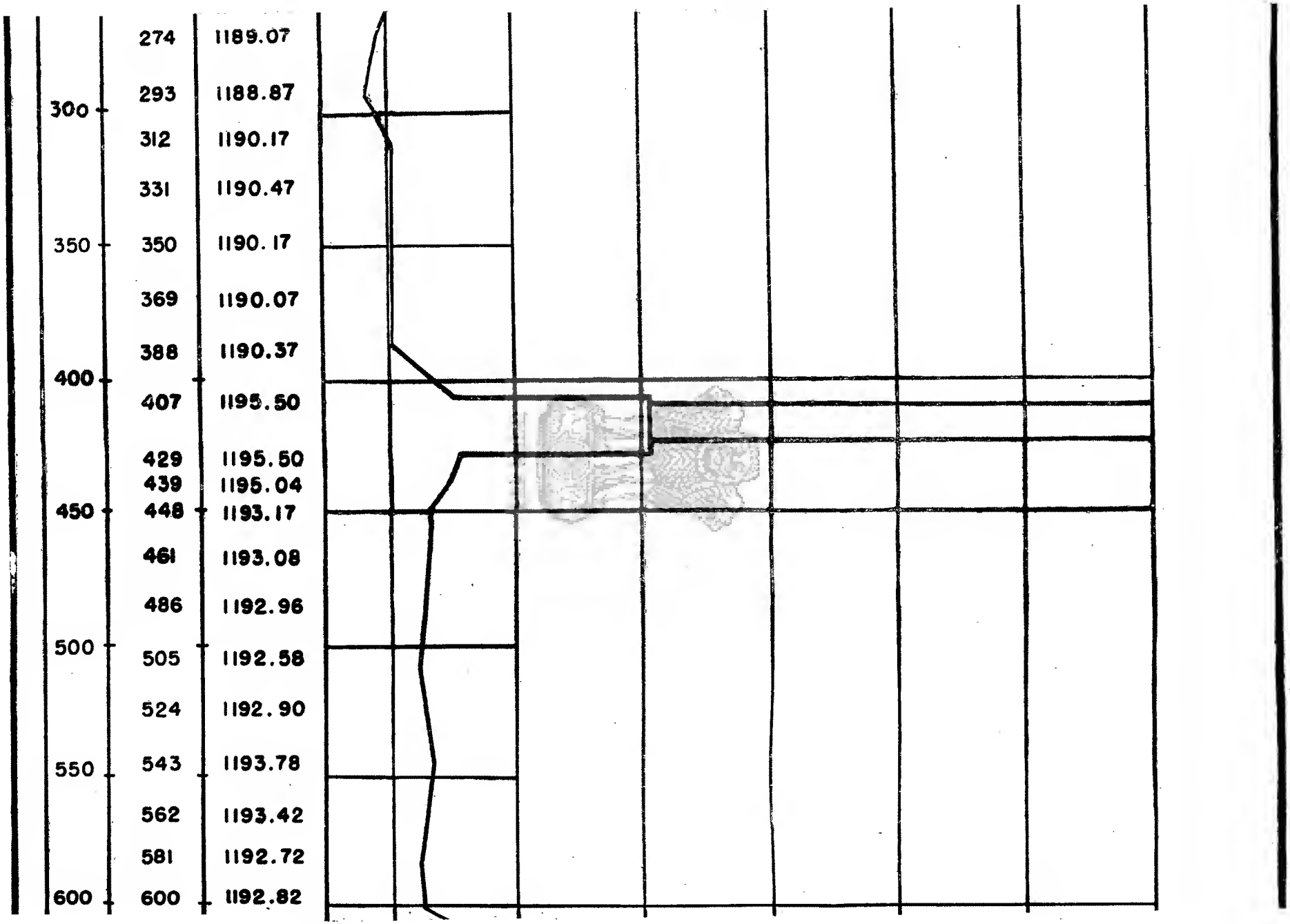
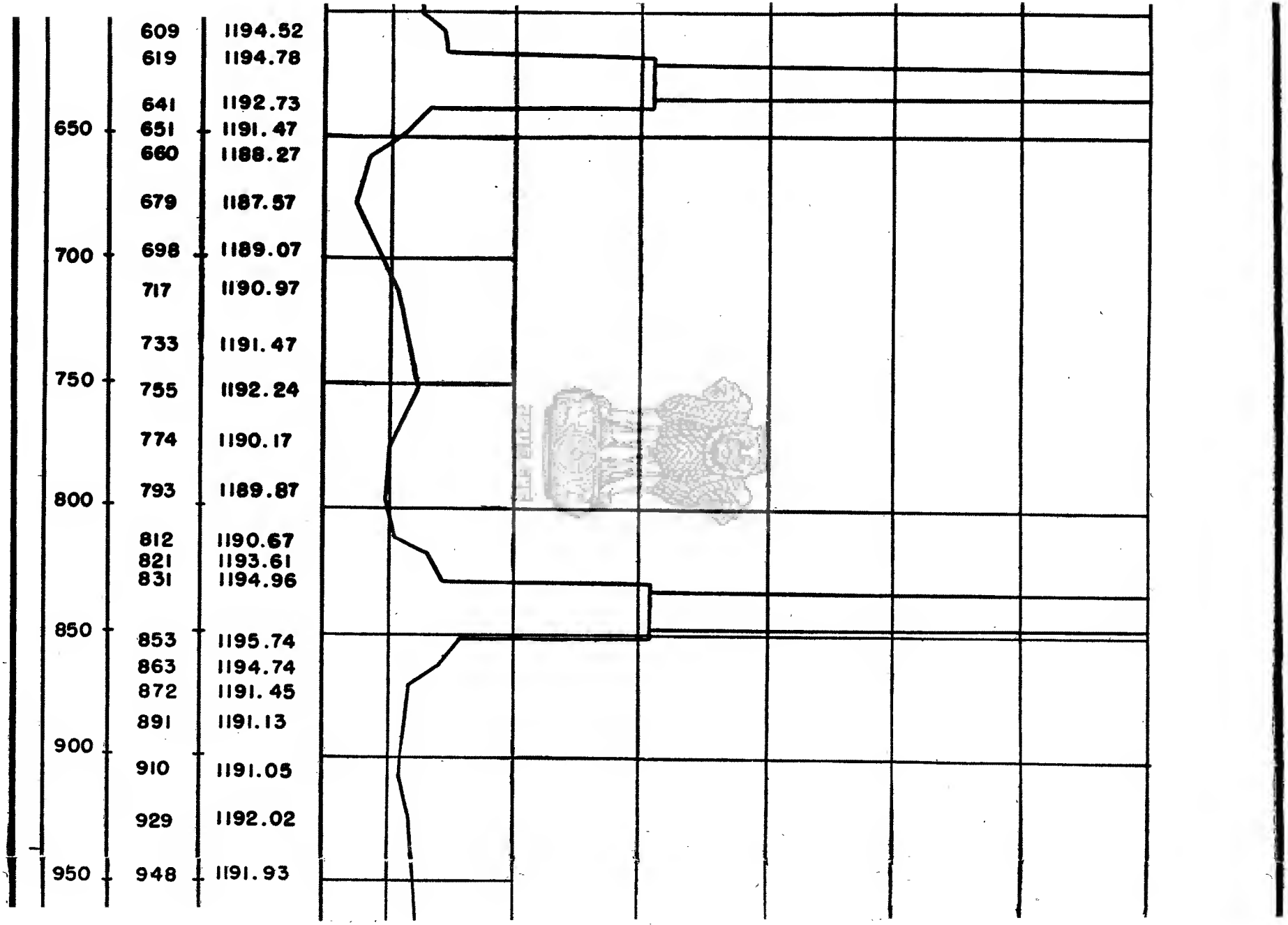

79°
45"
80°
50"
BAHORIBUND
SIHORA
CHIPAGHAT
PATAN
PONDI
Hiran
PARIAT
ADHARTAL
JABALPUR
Narmada R.
SANKALGHAT
65"
BARERAKALAN
NIWAS
BARGI
IRWARA
NARSINGHPUR
Sher
NARAYANGANJ
Shakkar
Narmada
HARAI
GHANSORE
LAKHNADON
MANDLA
55"
60"
65"
Banjar
BICHHIA
PARASWADA
BAIHAR
50"
HINDWARA
LEGEND
CATCHMENT BOUNDARY
SUB-CATCHMENT BOUNDARY
I. M. D. RAINGAUGE STATIONS
ISOHYETALS
DAM SITES
ZONAL BOUNDARY
STATE BOUNDARY
GAUGE-DISCHARGE SITE
GAUGE SITE

PLATE V-1


81°
N
23°
DINDORI
Narmada R.
PPER
HILLY
AREA
BAJAG
Burhner
ICHHIA
HAR
JAGLA
22°
SÄLETEKA
55"
50"
45"
81°


1250.0
1240.0
1230.0
1220.0
1210.0
1200.0
1190.0
1185.0
DATUM LINE
REDUCED LEVEL
1249.56
1238.47
1236.41
1233.14
1225.16
1218.96
1212.28
1196.89
1196.09
1189.97
1189.87
1190.57
1191.47
1196.15
1195.58
1194.88
1191.17
1190.57
DISTANCE IN FEET
0
7
20
37
58
63
78
97
117
125
136
155
176
182
195
217
227
236
255
50
00
50
00
50


274 1189.07
293 1188.87
300
312 1190.17
331 1190.47
350
350 1190.17
369 1190.07
388 1190.37
400
407 1195.50
429 1195.50
439 1195.04
450
448 1193.17
461 1193.08
486 1192.96
500
505 1192.58
524 1192.90
550
543 1193.78
562 1193.42
581 1192.72
600
600 1192.82

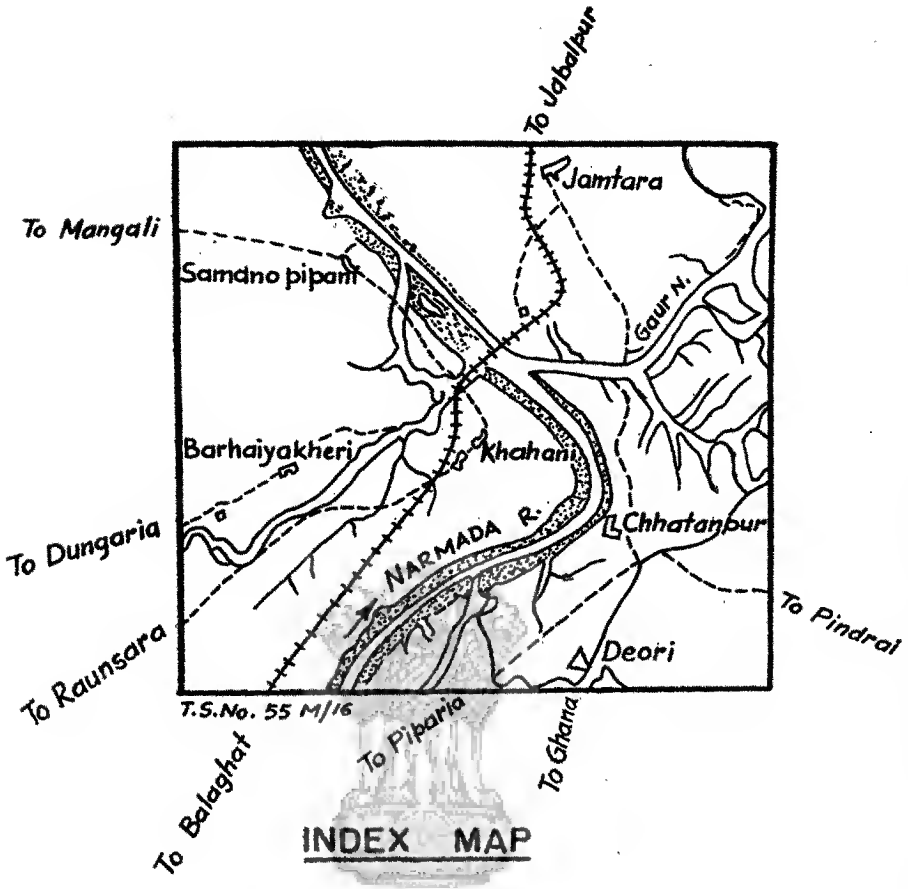

609 1194.52
619 1194.78
641 1192.73
650
651 1191.47
660 1188.27
679 1187.57
700
698 1189.07
717 1190.97
733 1191.47
750
755 1192.24
774 1190.17
800
793 1189.87
812 1190.67
821 1193.61
831 1194.96
850
853 1195.74
863 1194.74
872 1191.45
891 1191.13
900
910 1191.05
929 1192.02
950
948 1191.93

CROSS
NARM

JAMTARA

SCALE :—

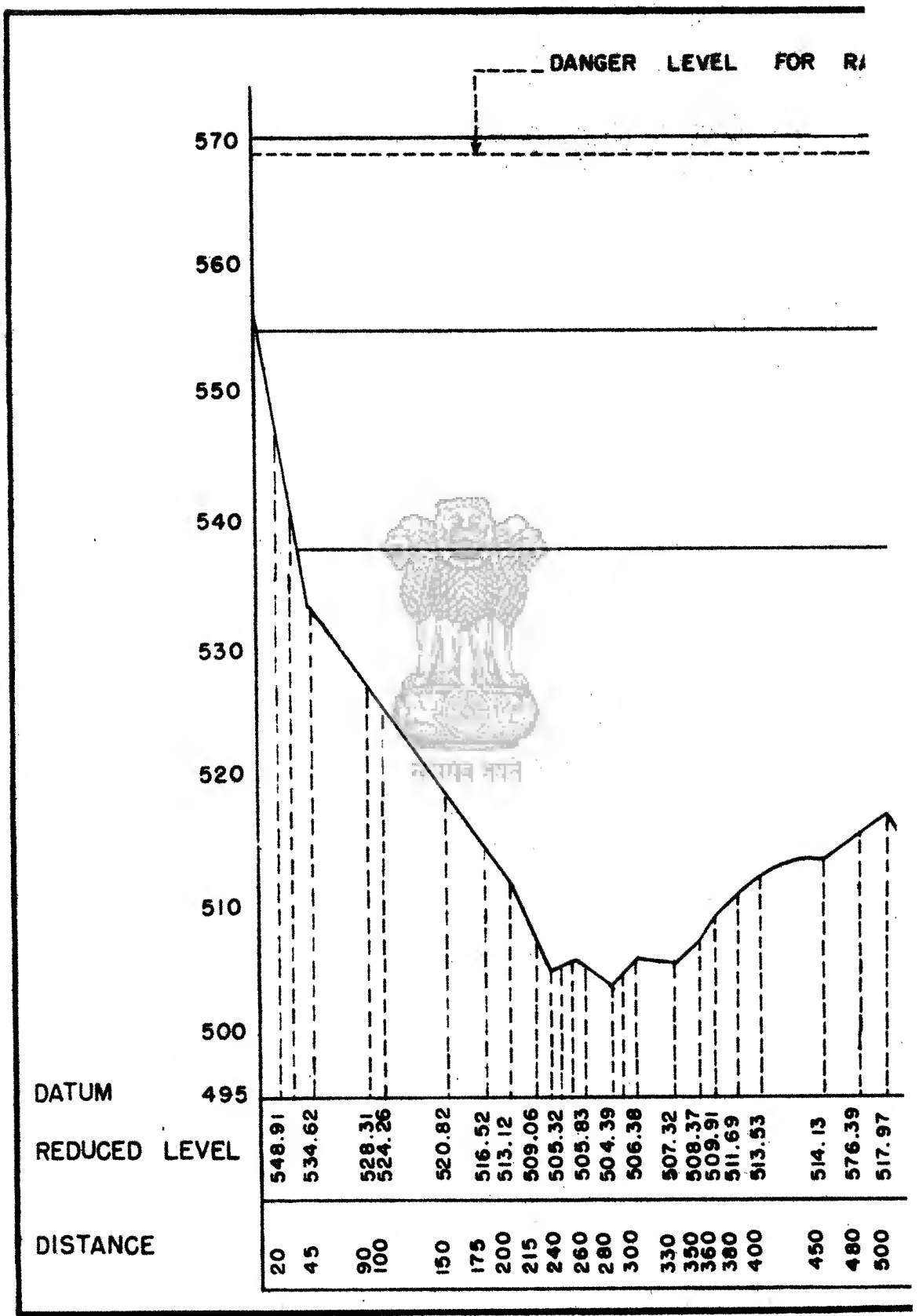
PLATE V-2



INDEX MAP

CROSS SECTION OF NARMADA RIVER AT AMTARA RAILWAY BRIDGE

SCALE:— HOR. — 1 INCH = 50 FEET
VER. — 1 INCH = 10 FEET



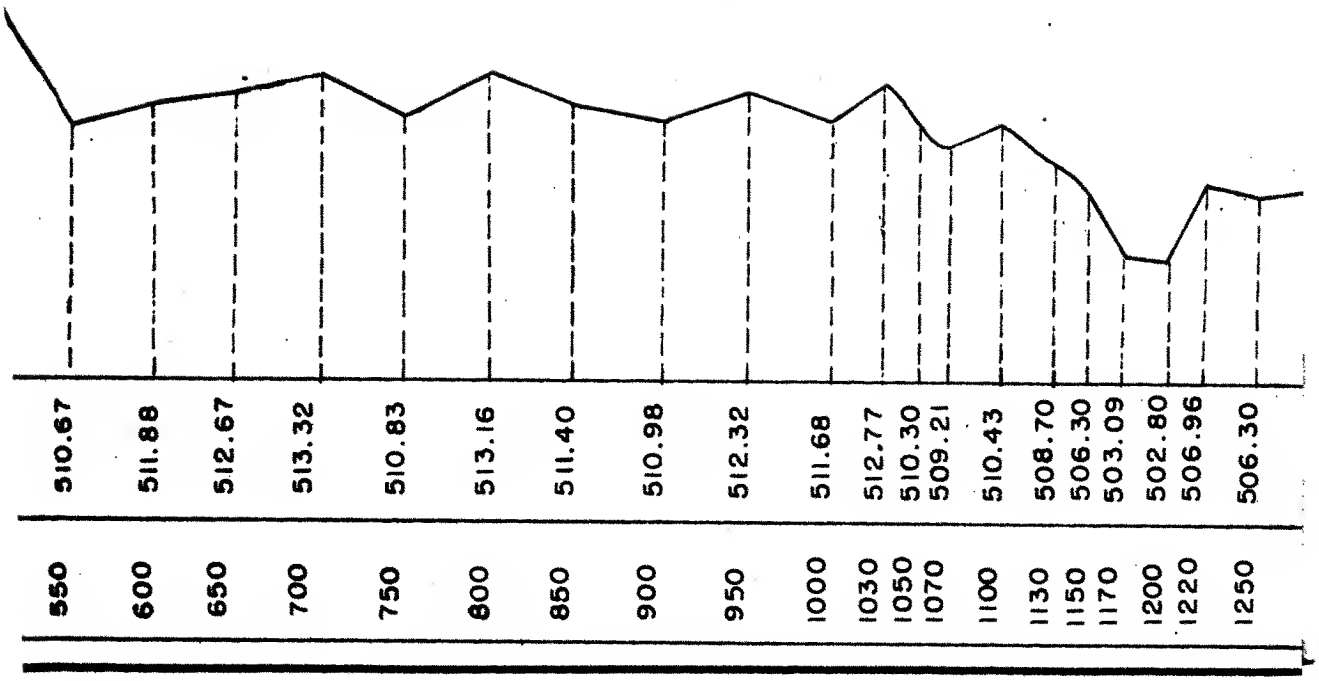
O.G.P. SCHOOL (LITHO)

ILWAY BRIDGE R. L. 569.33

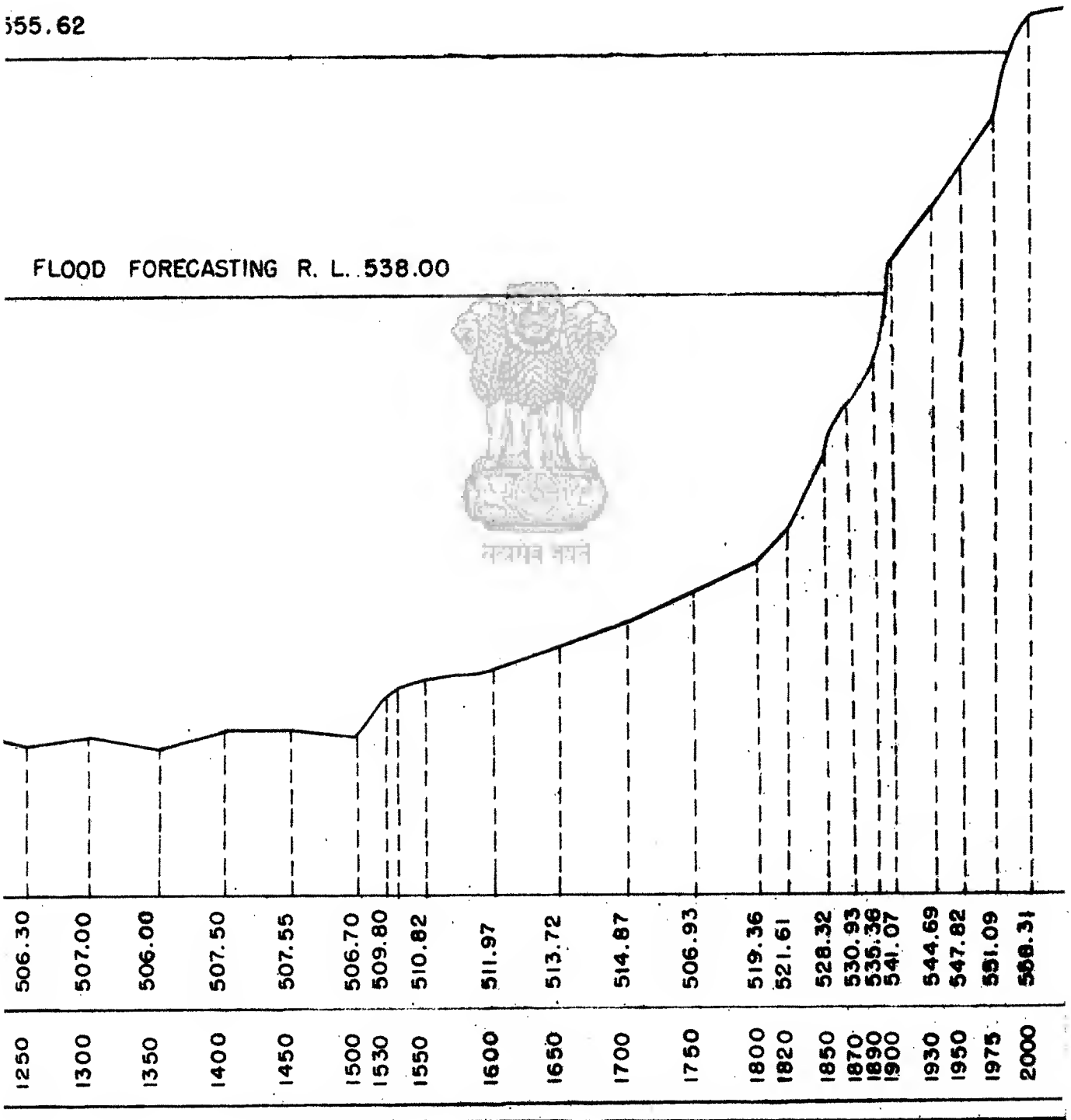
HIGHEST FLOOD LEVEL R. L. 570.43 RECORDED ON

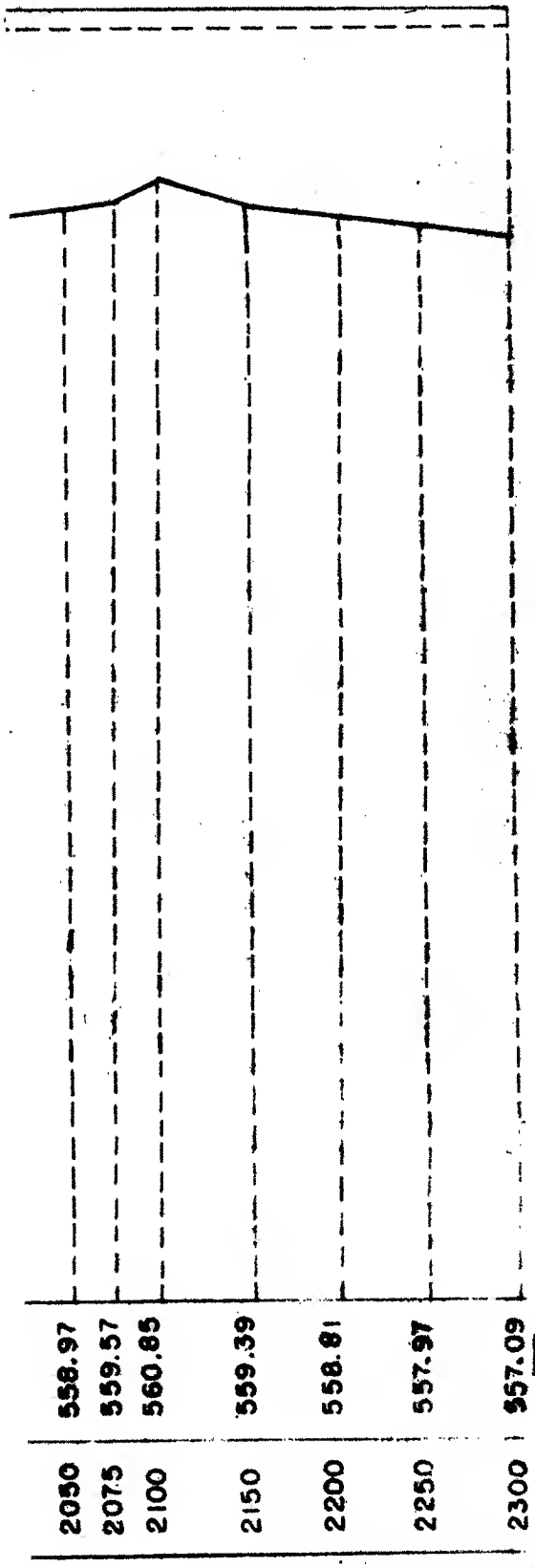
DANGER LEVEL FOR ROAD BRIDGE 555.

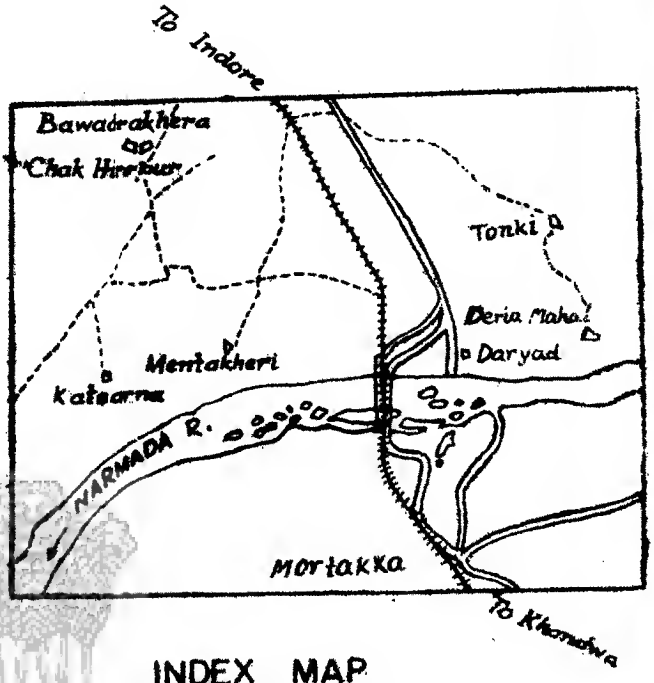
DANGER LEVEL FOR FI



ON 16-9-61 TO 17-9-61



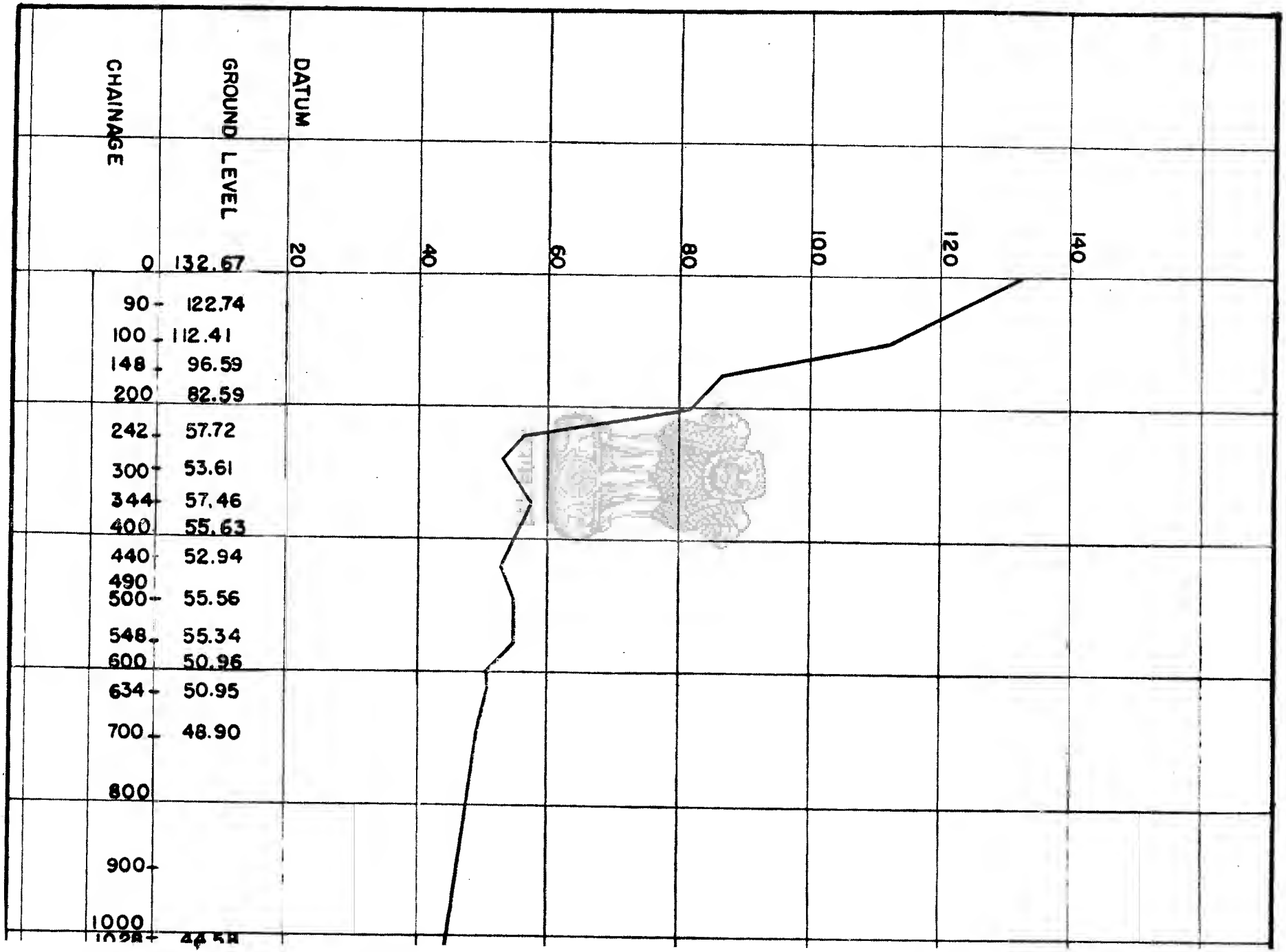




INDEX MAP

CROSS SECTION OF NARMADA RIVER AT MORTAKKA DISCHARGE SITE

SCALE :— HOR. — 1 INCH = 100 FEET
VER. — 1 INCH = 10 FEET


CHAINAGE
GROUND LEVEL
DATUM
20
40
60
80
100
120
140
0 132.67
90 - 122.74
100 - 112.41
148 - 96.59
200 82.59
242 - 57.72
300 - 53.61
344 - 57.46
400 55.63
440 - 52.94
490
500 - 55.56
548 - 55.34
600 50.96
634 - 50.95
700 - 48.90
800
900 -
1000
1028 - 44.58

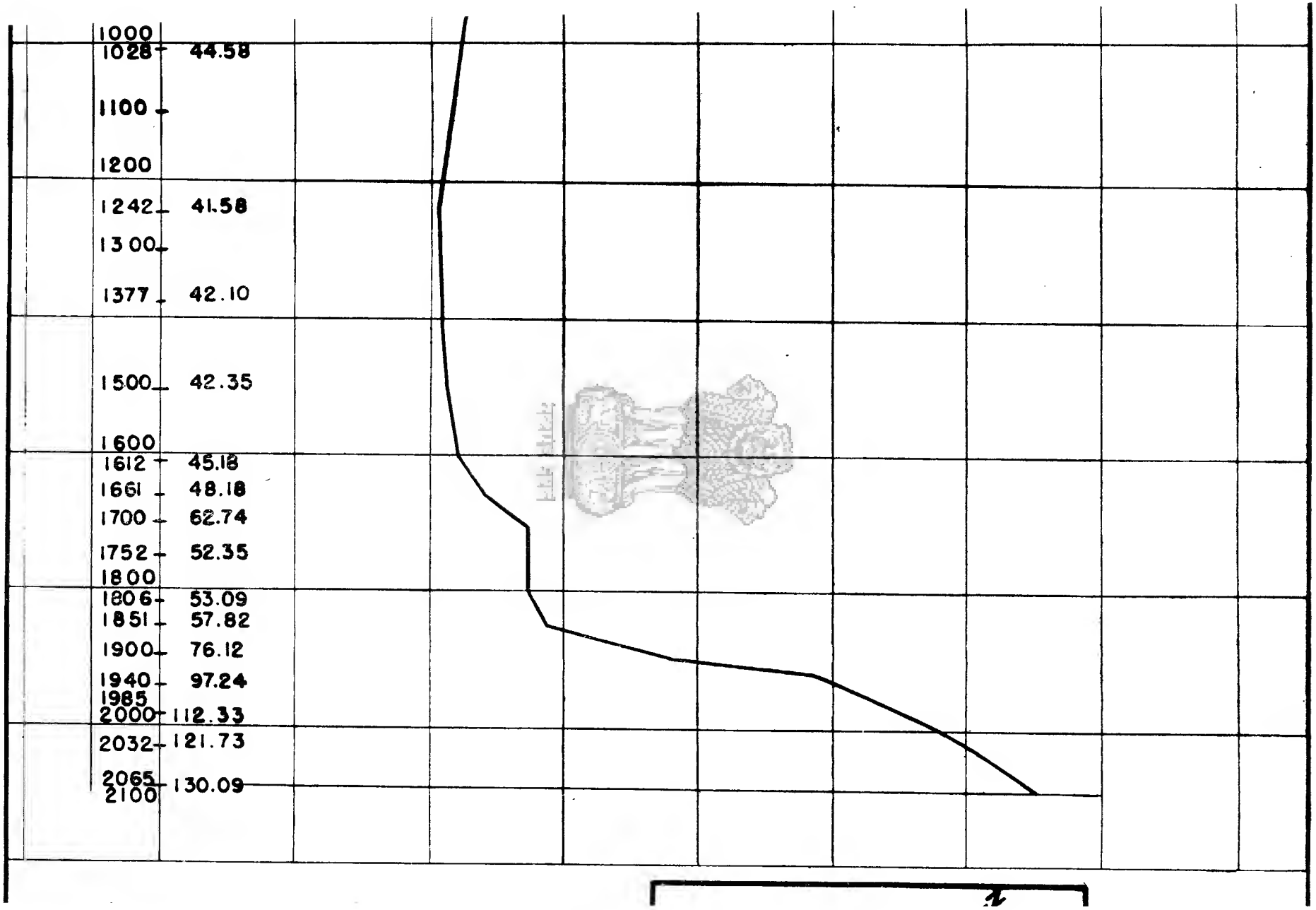
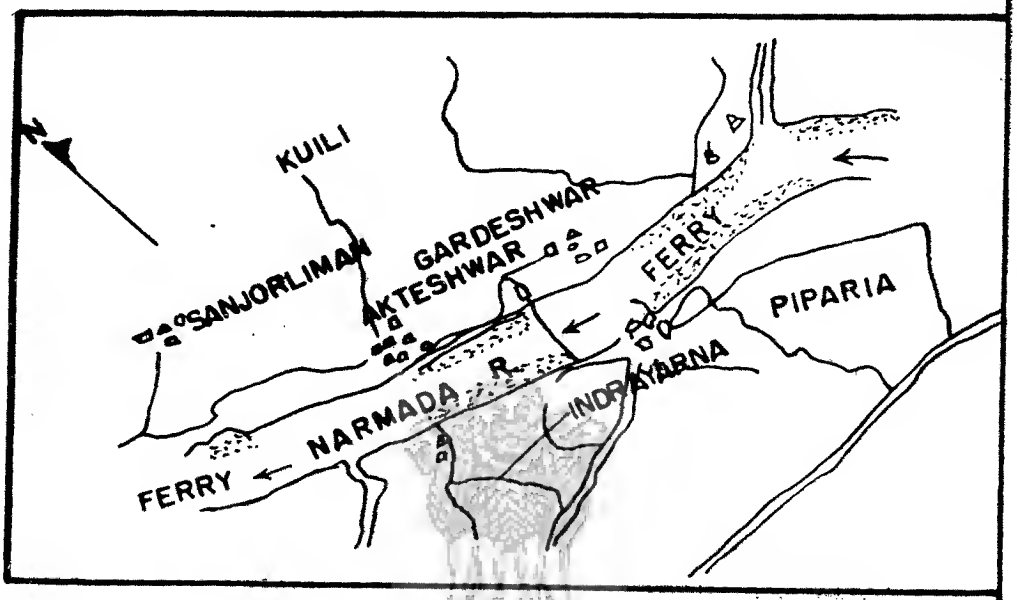

1000
1028 44.58
1100
1200
1242 41.58
1300
1377 42.10
1500 42.35
1600
1612 45.18
1661 48.18
1700 62.74
1752 52.35
1800
1806 53.09
1851 57.82
1900 76.12
1940 97.24
1985
2000 112.33
2032 121.73
2065 130.09
2100

PLATE V-4

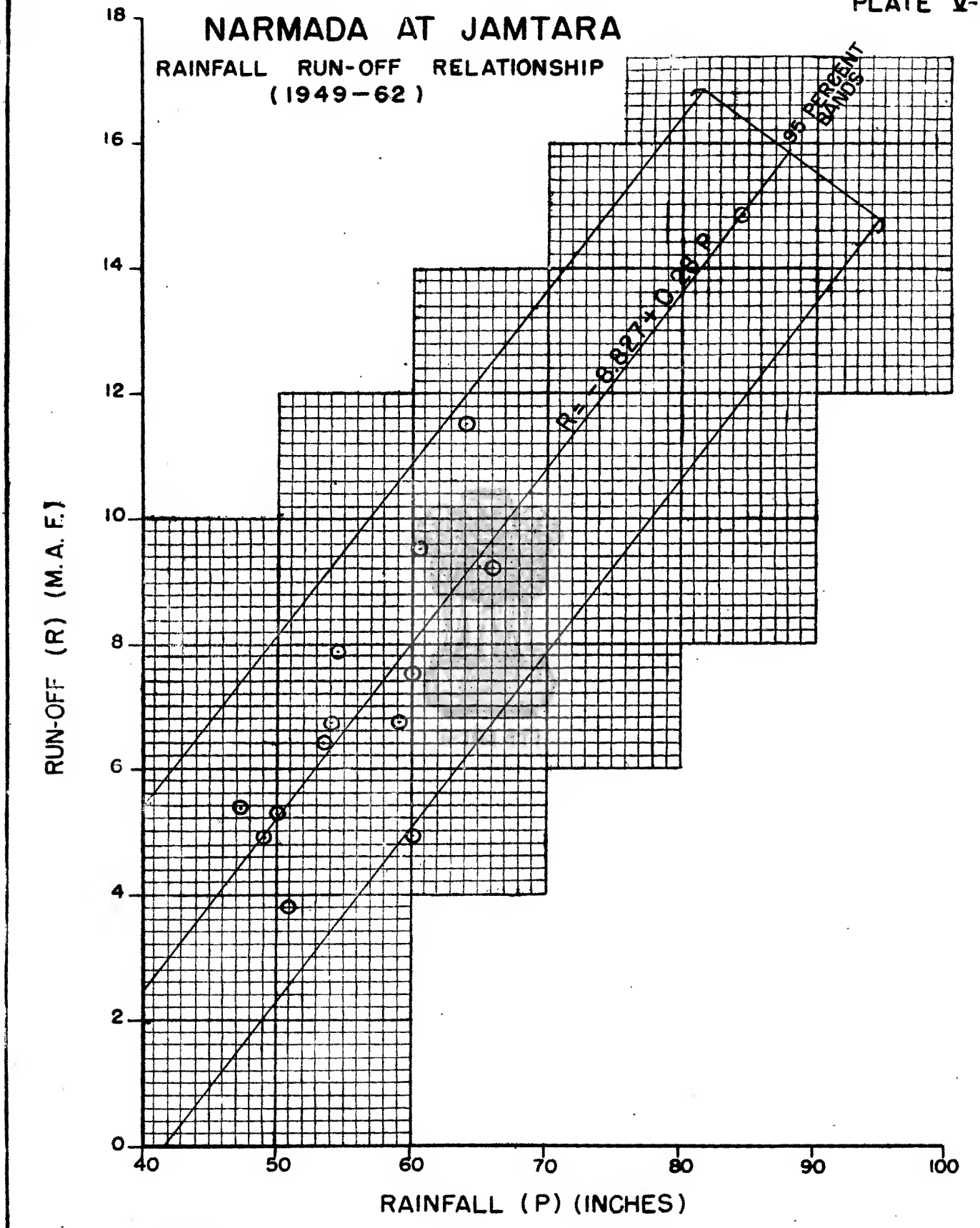


INDEX MAP

CROSS SECTION OF RIVER NARMADA AT GARDESHWAR GAUGE SITE

SCALE :— HOR. 1" = 200 FT.
VER. 1" = 20 FT.

PLATE V-6


NARMADA AT JAMTARA
RAINFALL RUN-OFF RELATIONSHIP
(1949-62)
95 PERCENT BANDS
R = -0.827 + 0.28 P
RUN-OFF (R) (M.A.F.)
RAINFALL (P) (INCHES)
0
2
4
6
8
10
12
14
16
18
40
50
60
70
80
90
100

GROWTH OF I.M.D. RAINGAUGE NETWORK

1891 TO 1961

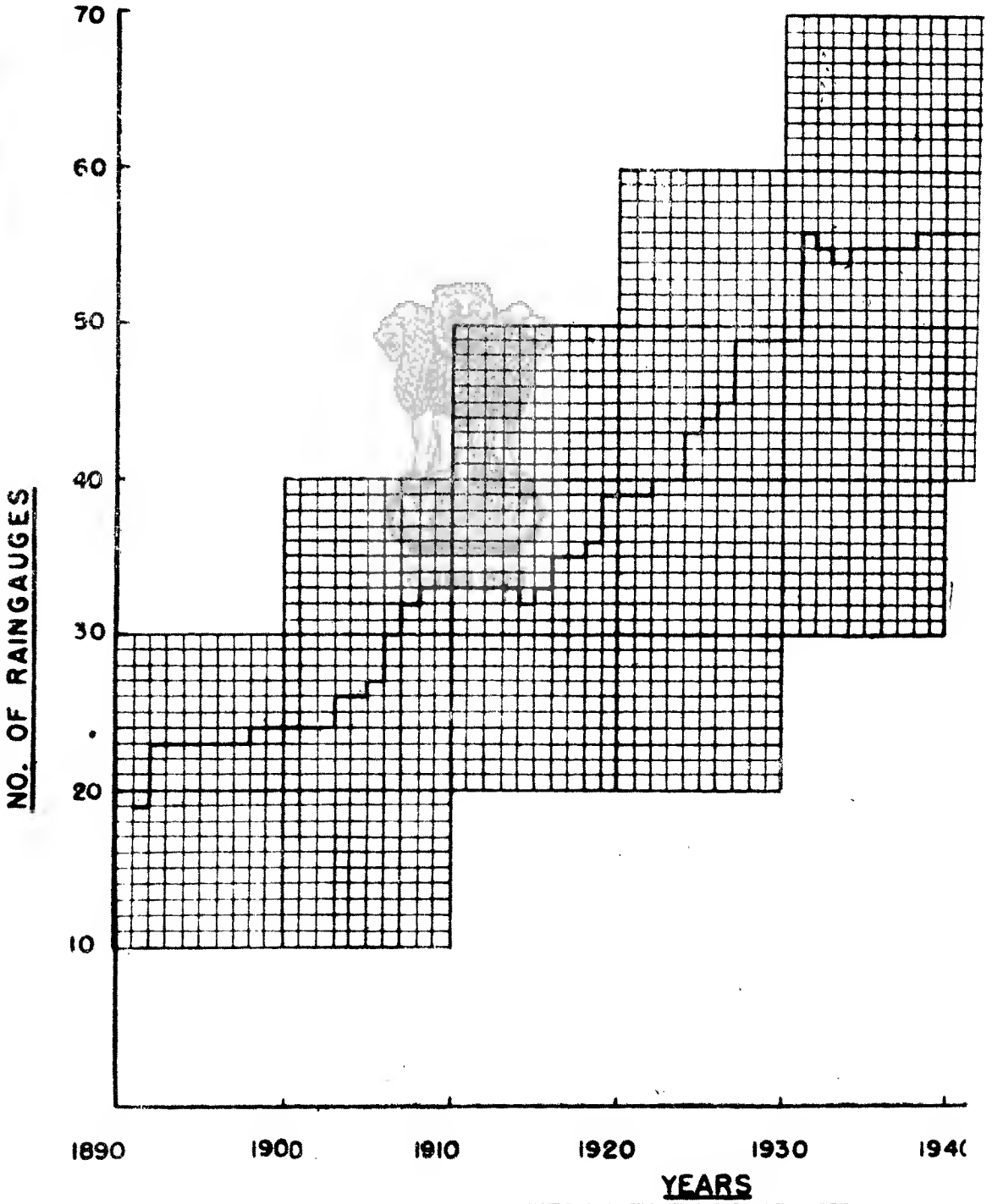
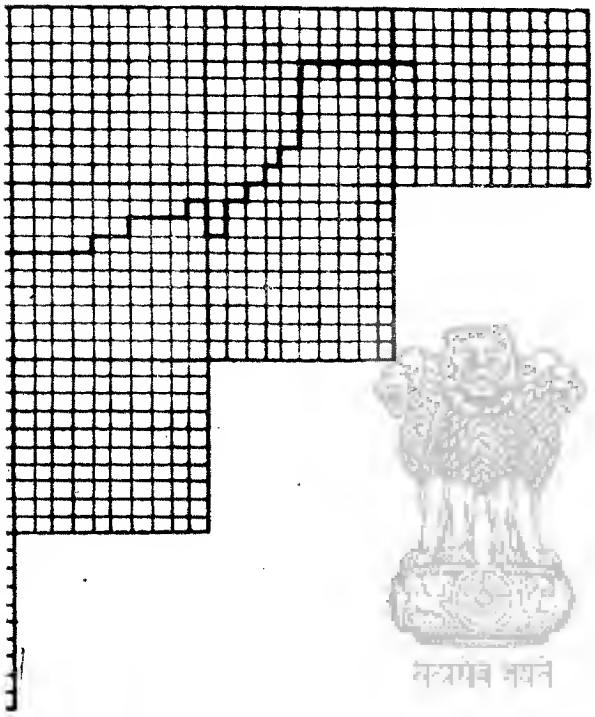


PLATE V-5

?K IN NARMADA BASIN

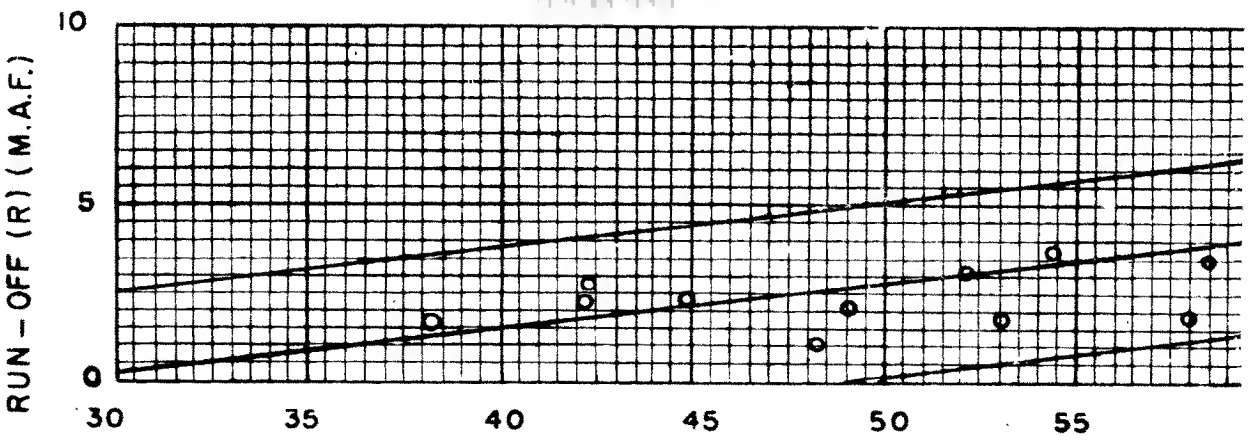


940 1950 1960 1970

NARMA

TAWA AT TAWA

RAINFALL RUN-OFF
(1949-

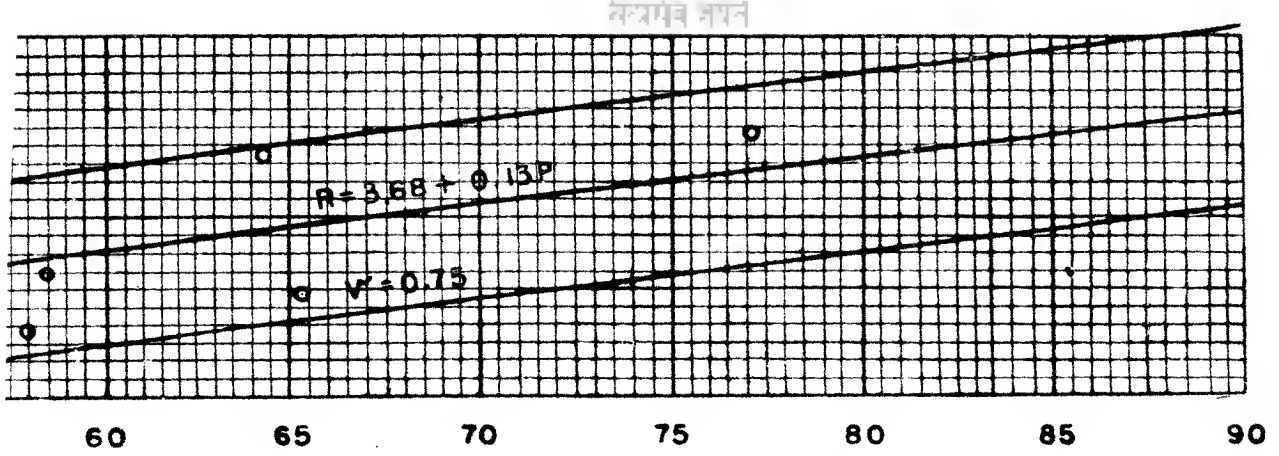


IADA

A RLY. BRIDGE

F RELATIONSHIP

-62)



(INCHES)

NARMADA

JAMTARA TO MORTAK
EXCLUDING TAWA

RAINFALL RUN-OFF RELA

(1949-62)

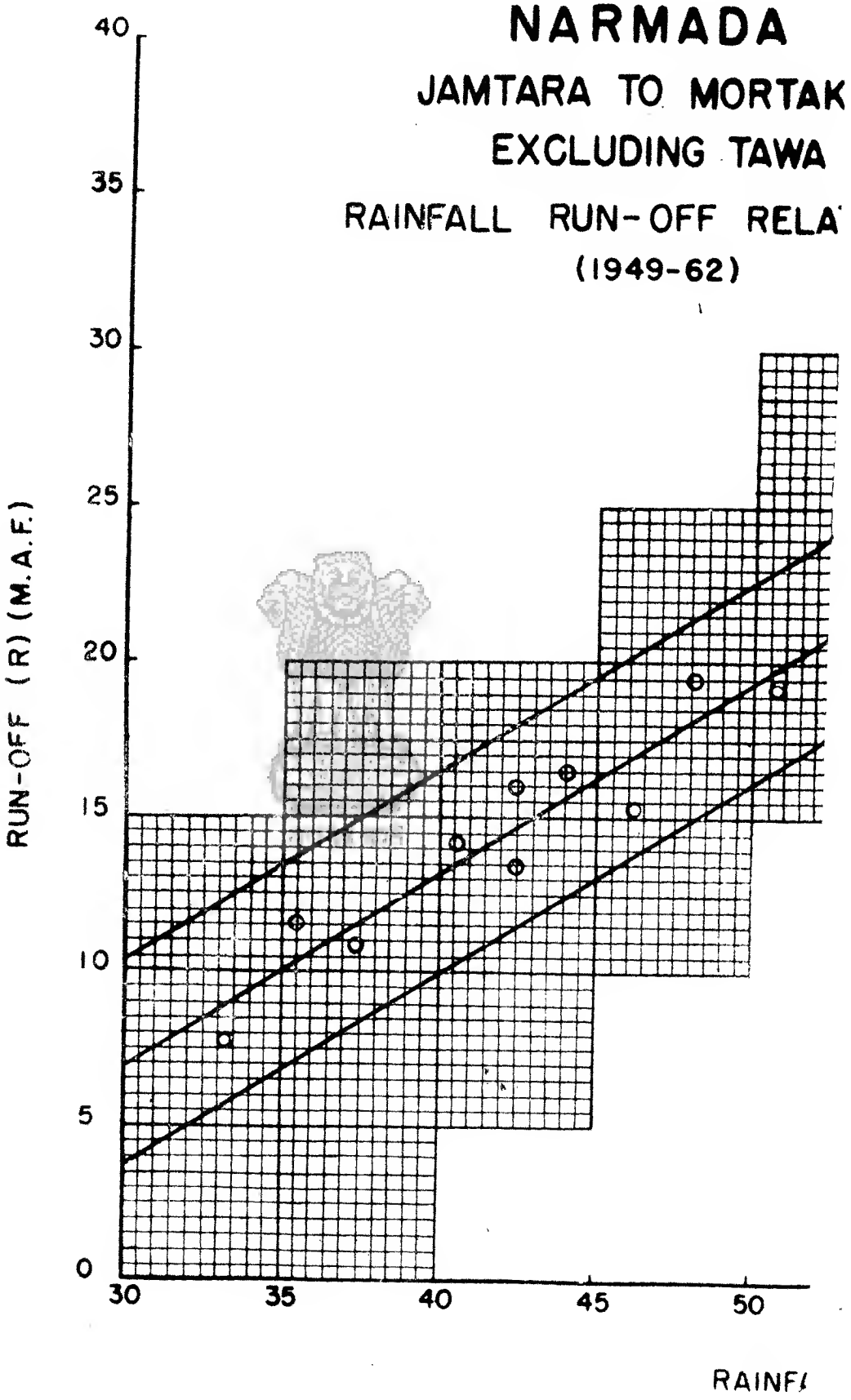
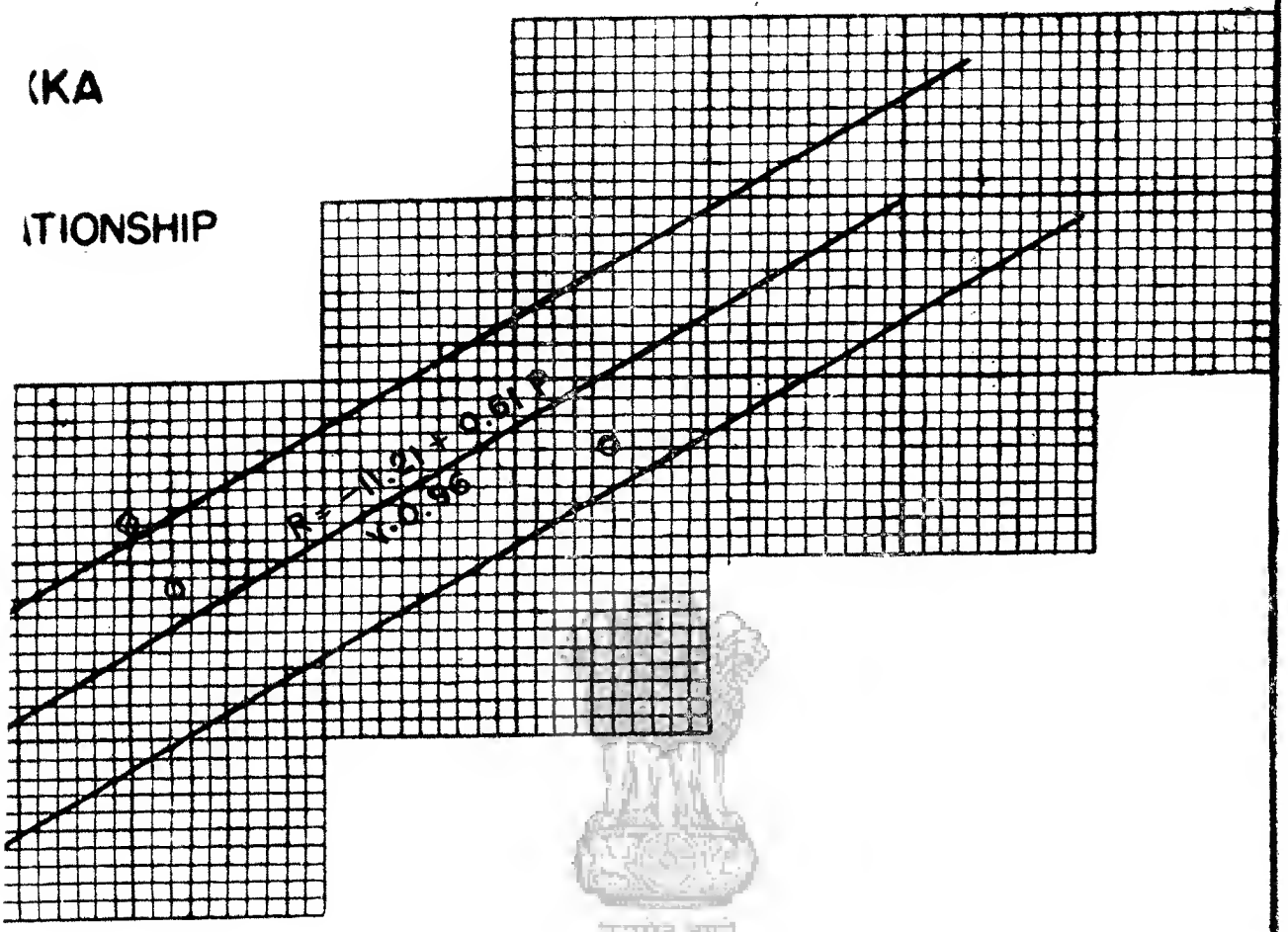


PLATE V-8

(KA

ITIONSHIP



55 60 65 70 75 80

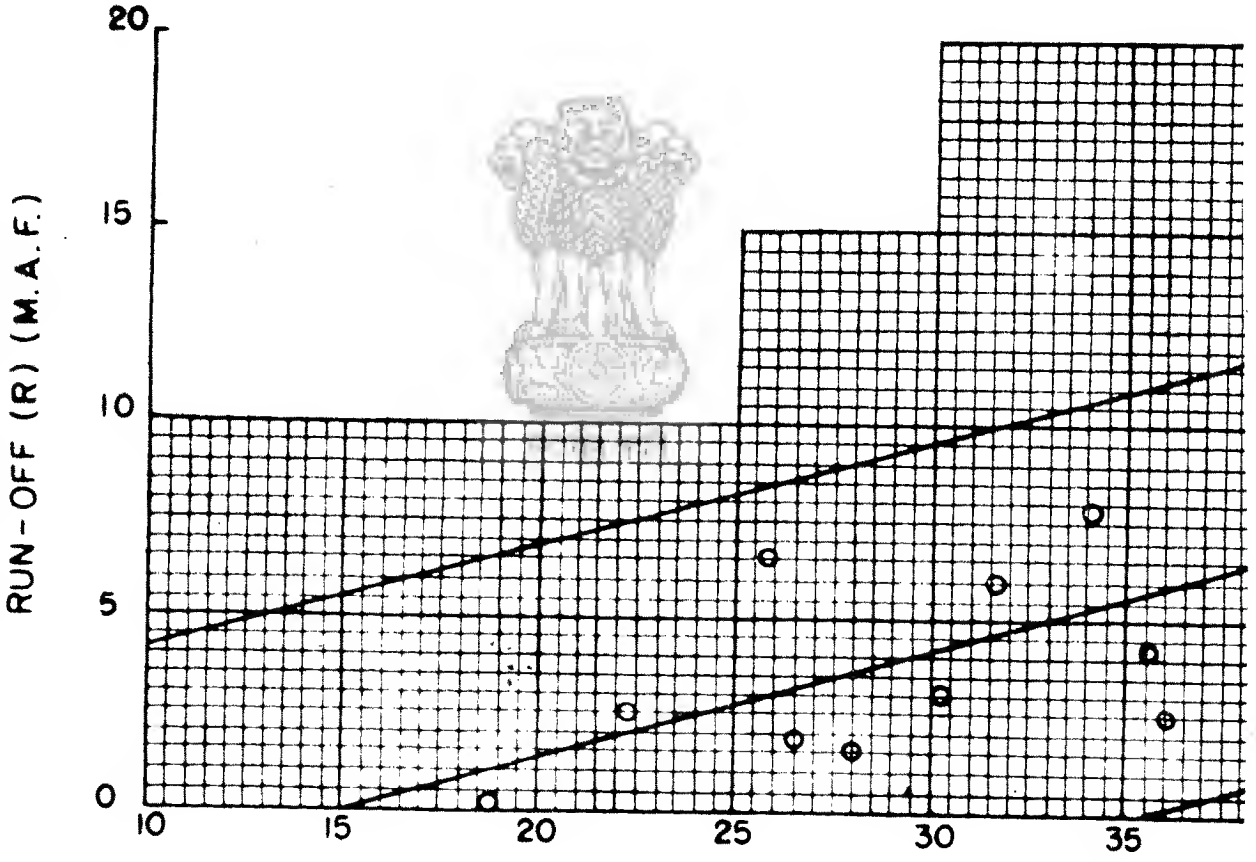
NFALL (P) (INCHES)

NAR

MORTAKKA T

RAINFALL RUN-

(194



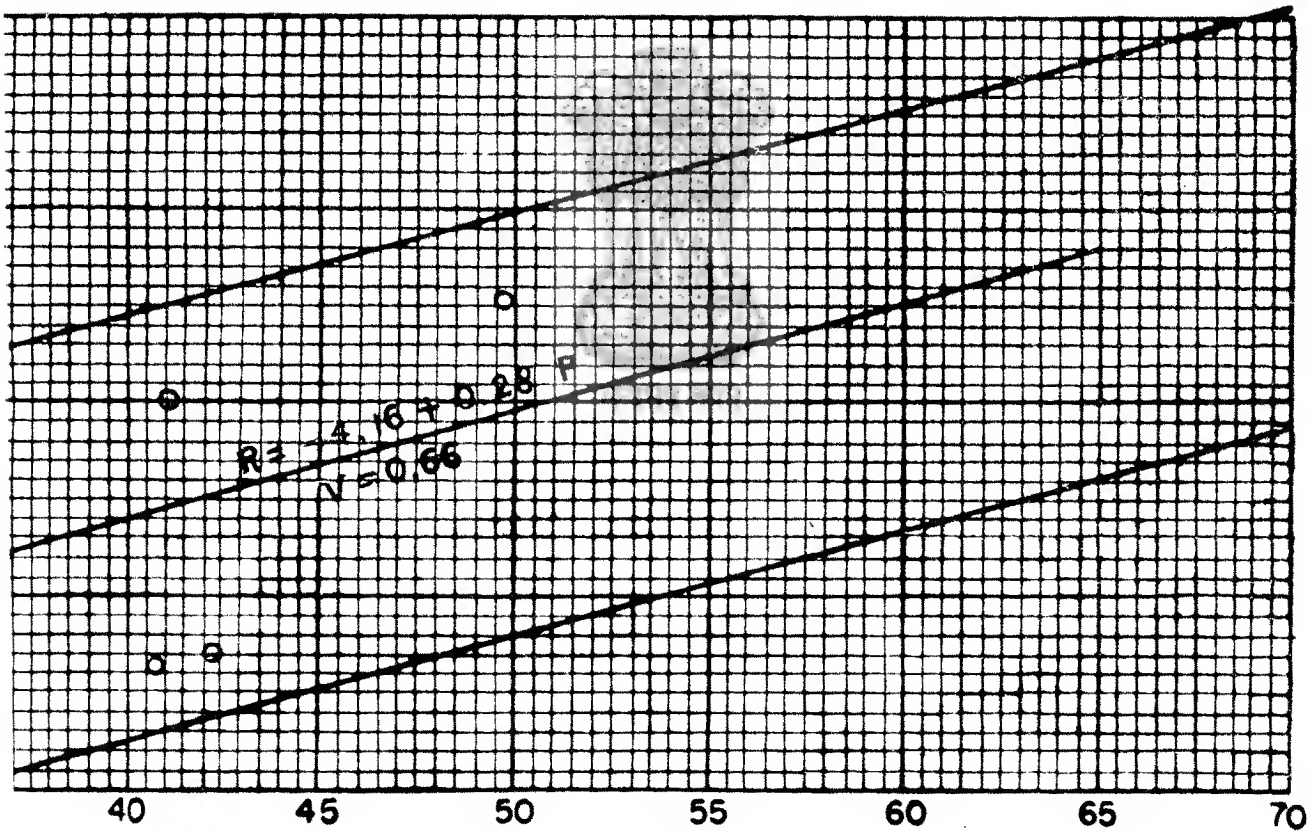
RAIN

RMADA

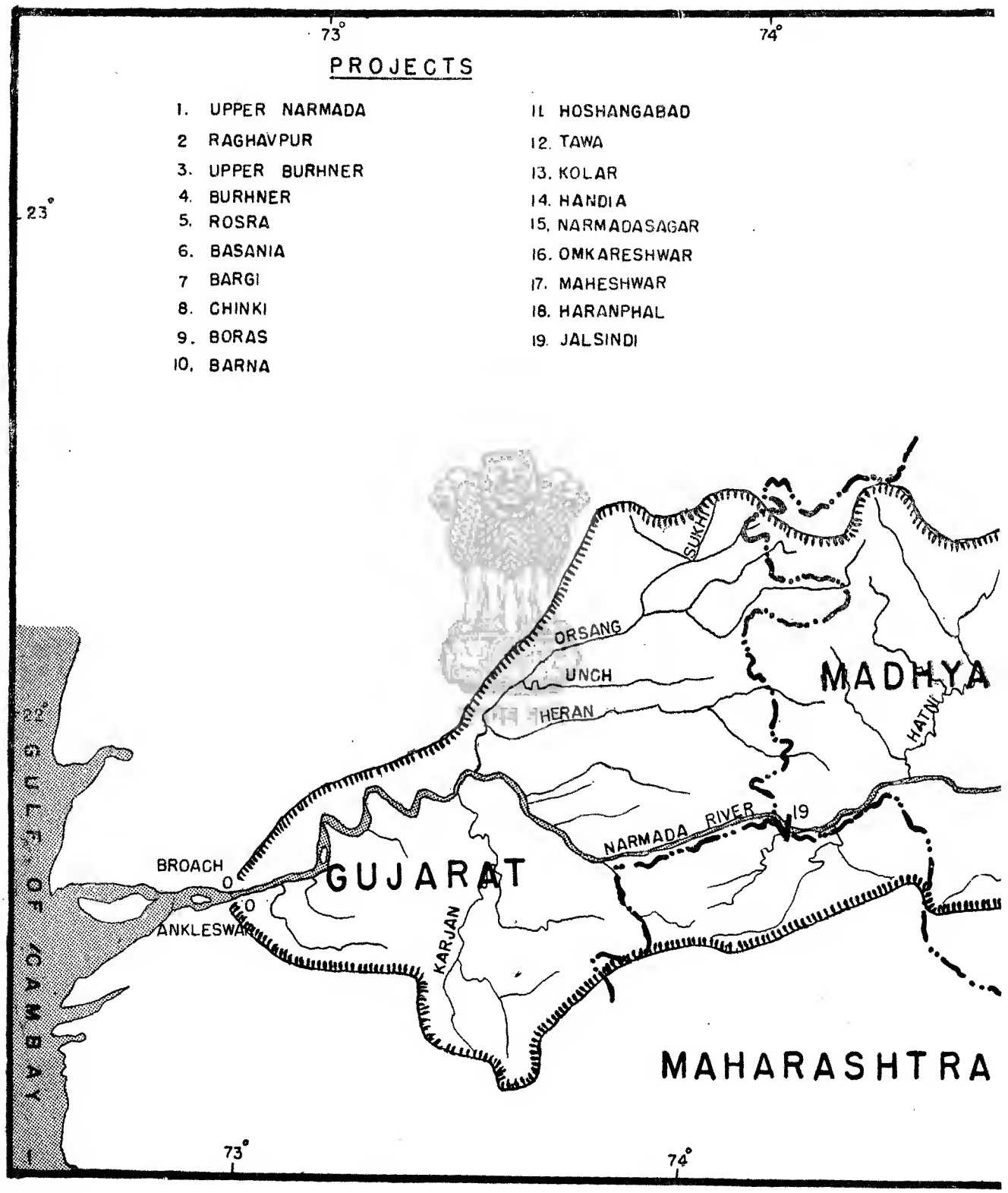
TO GARDESHWAR

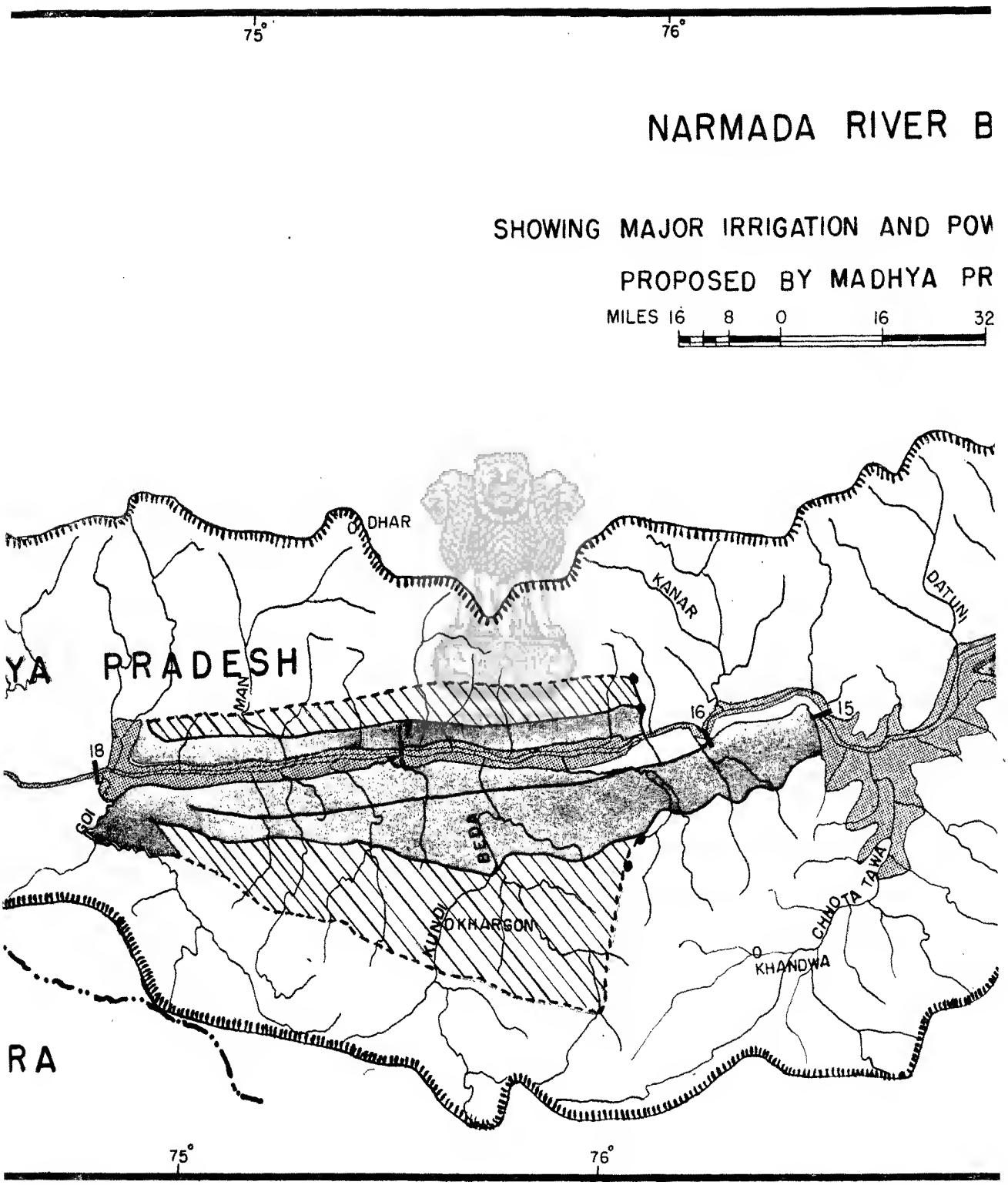
N-OFF RELATIONSHIP

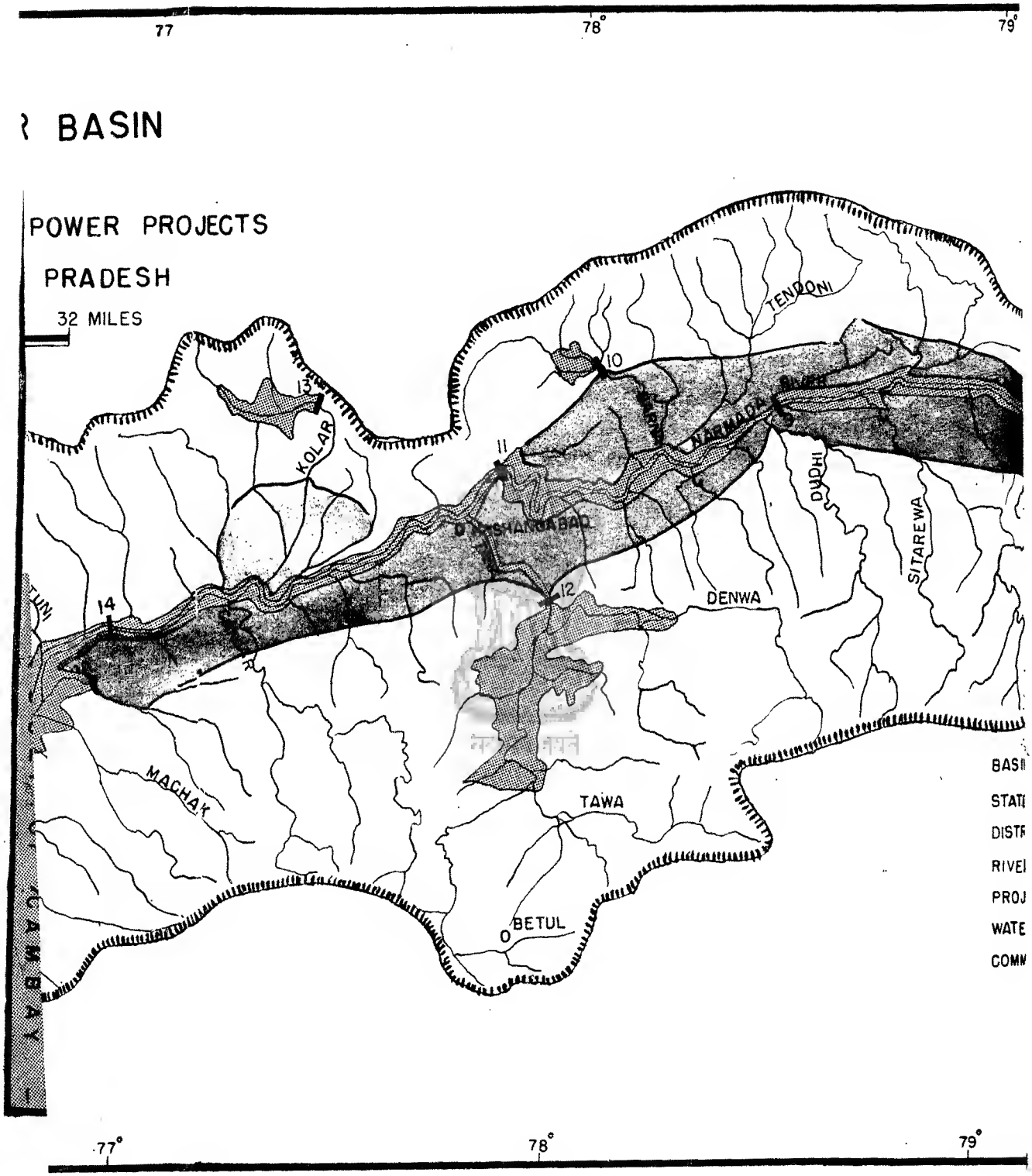
1949-62)



INFALL (P) (INCHES)


73°
74°
PROJECTS
1. UPPER NARMADA
2 RAGHAVPUR
3. UPPER BURHNER
4. BURHNER
5. ROSRA
6. BASANIA
7 BARGI
8. CHINKI
9. BORAS
10. BARNA
11. HOSHANGABAD
12. TAWA
13. KOLAR
14. HANDIA
15. NARMADASAGAR
16. OMKARESHWAR
17. MAHESHWAR
18. HARANPHAL
19. JALSINDI
23°
22°
SUKHI
ORSANG
UNCH
HERAN
MADHYA
HATNI
NARMADA RIVER
19
BROACH
GUJARAT
ANKLESWAR
KARJAN
MAHARASHTRA
GULF OF CAMBAY
73°
74°


75°
76°
NARMADA RIVER B
SHOWING MAJOR IRRIGATION AND POW
PROPOSED BY MADHYA PR
MILES 16 8 0 16 32
DHAR
KANAR
DATUNI
YA PRADESH
MAN
18
16
15
GOI
BEDA
KUNDI
KHARGON
CHHOTA TAWA
KHANDWA
RA
75°
76°


77
78°
79°
BASIN
POWER PROJECTS
PRADESH
32 MILES
TENDONI
10
13
KOLAR
11
NARMADA
DUDHI
SITAREWA
HOSHANGABAD
12
DENWA
14
MACHAK
TAWA
BETUL
BASI
STAT
DIST
RIVE
PROJ
WATE
COMM
77°
78°
79°

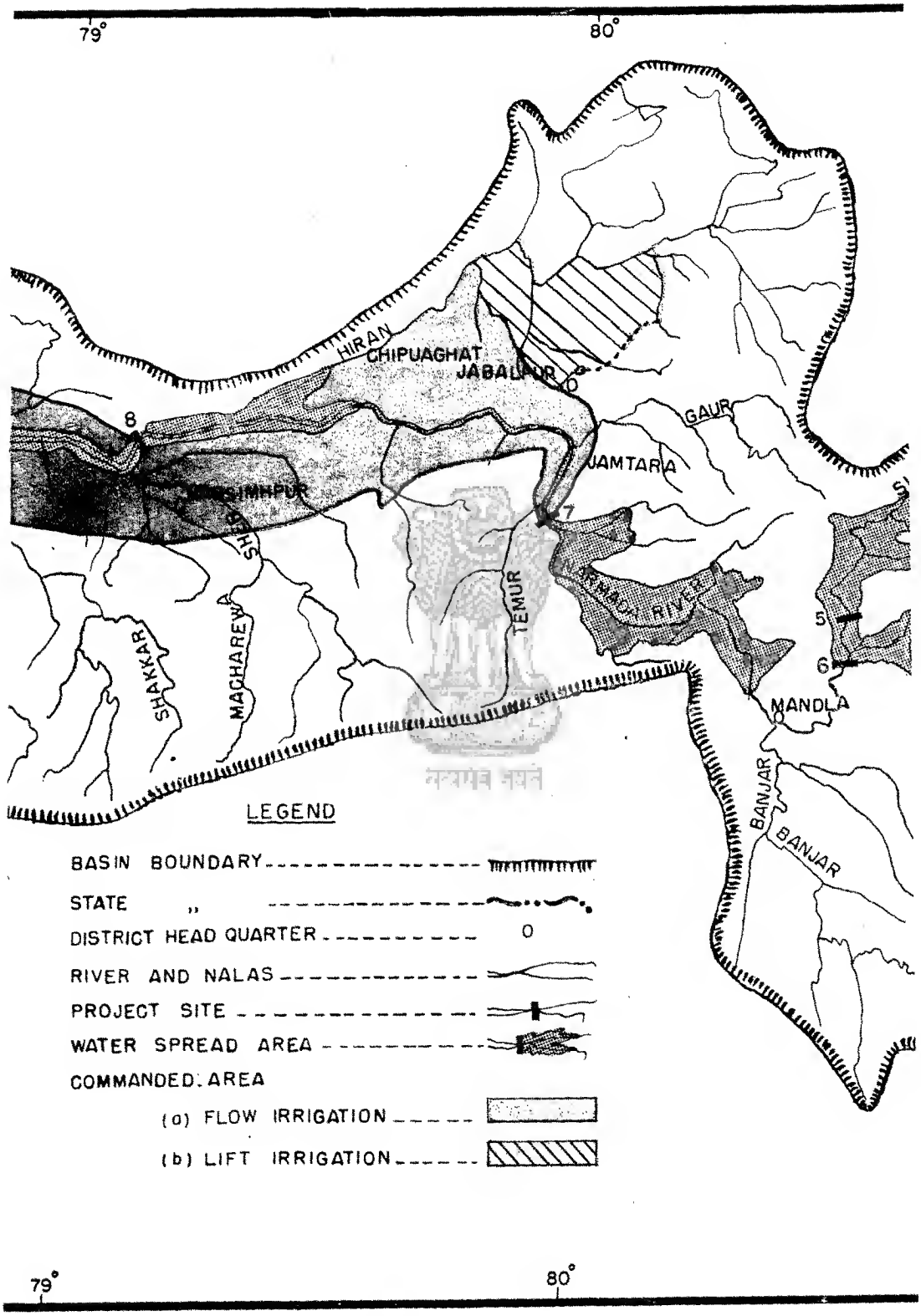
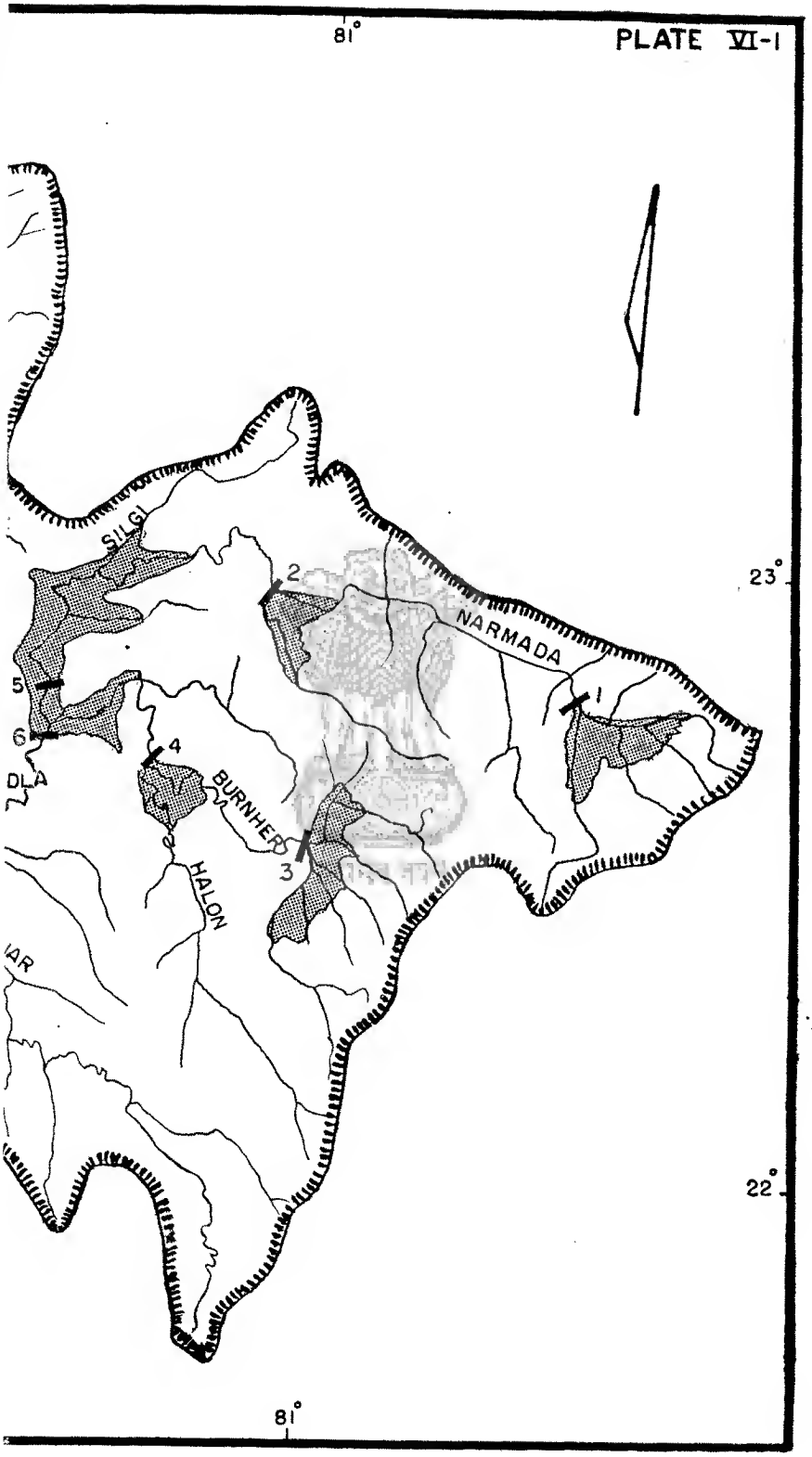

79°
80°
HIRAN
CHIPUAGHAT
JABALPUR
GAUR
JAMTARA
8
7
5
6
SHAKKAR
MACHAREWA
TEMUR
MANDLA
BANJAR
BANJAR
LEGEND
BASIN BOUNDARY
STATE ,,
DISTRICT HEAD QUARTER
RIVER AND NALAS
PROJECT SITE
WATER SPREAD AREA
COMMANDED AREA
(a) FLOW IRRIGATION
(b) LIFT IRRIGATION
79°
80°

PLATE VI-1



TAIL RACE LEVEL	80	210		355	470	535
PROJECT	NAVGAM	JALGINDHI		HARANPHAL	MANESHWAR	OMKARESH-WAR
BED LEVEL	32	197		343	460	524
MILEAGE	723	689	669	650	595	559

L. SECTION OF NARMADA RIVER

SHOWING MAJOR IRRIGATION & POWER PROJECTS

(PROPOSED BY MADHYA PRADESH)

SCALE :— HOR. — 1 INCH = 40 MILES
VER. — 1 INCH = 800 FEET

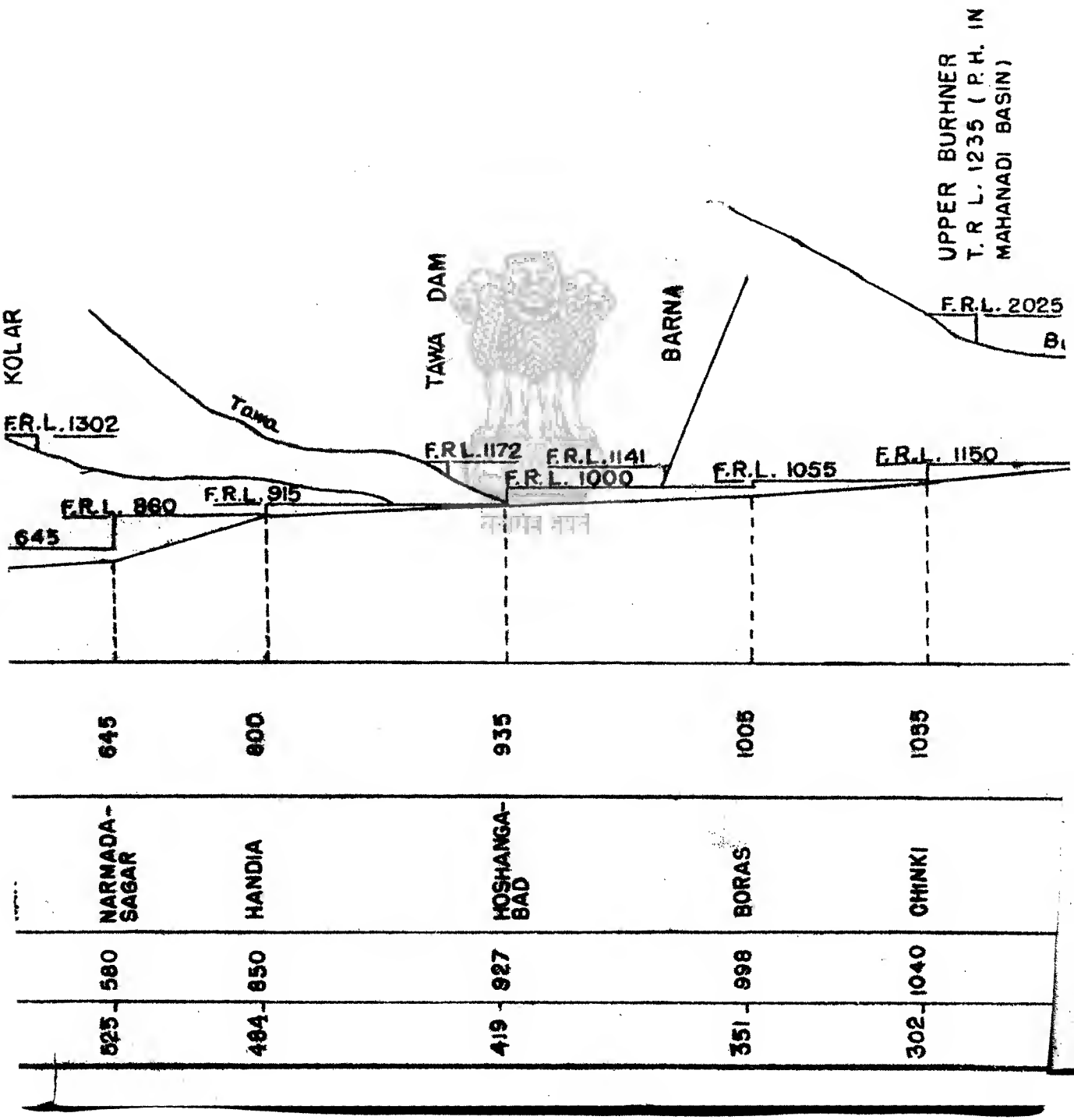
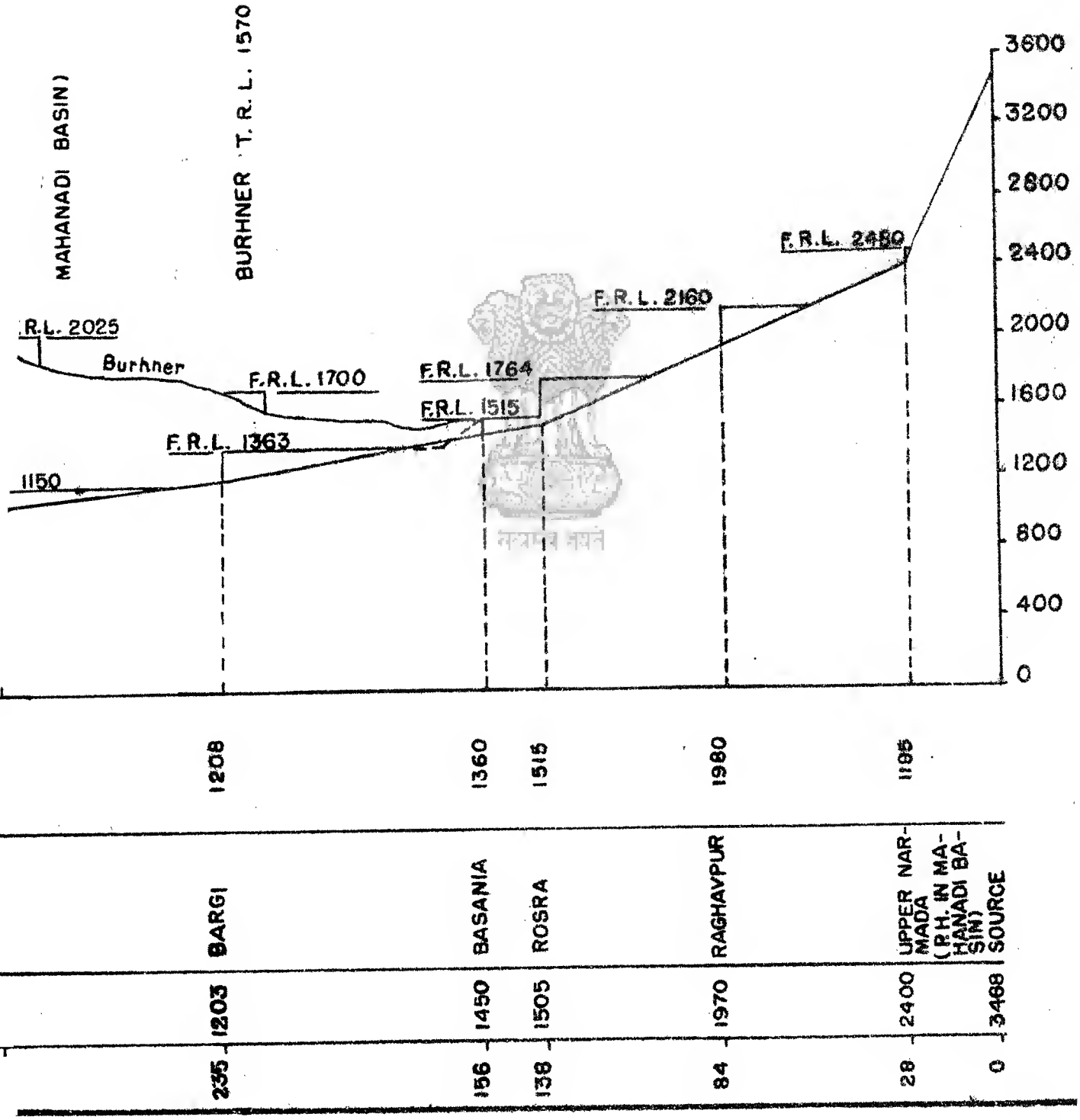
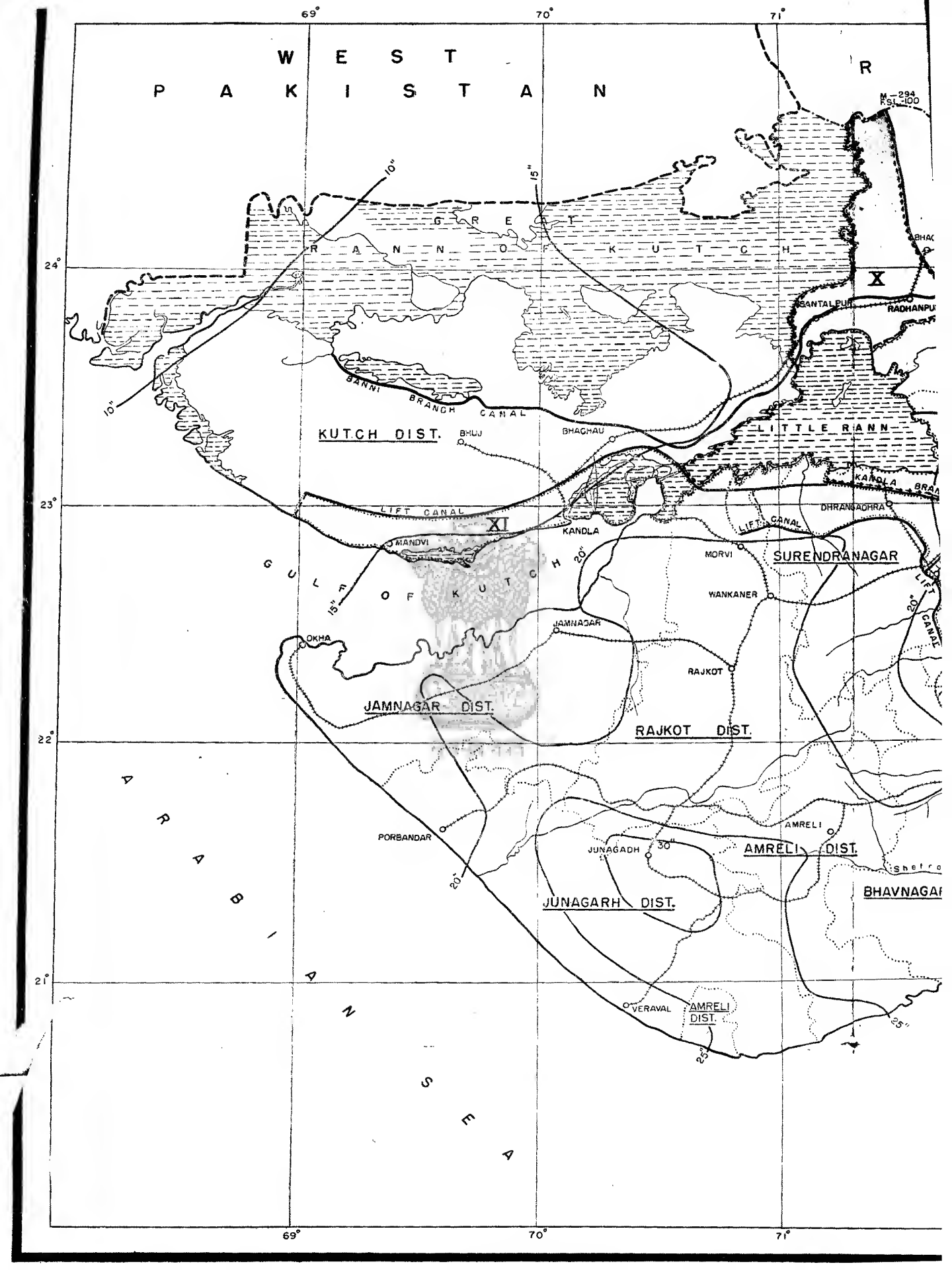
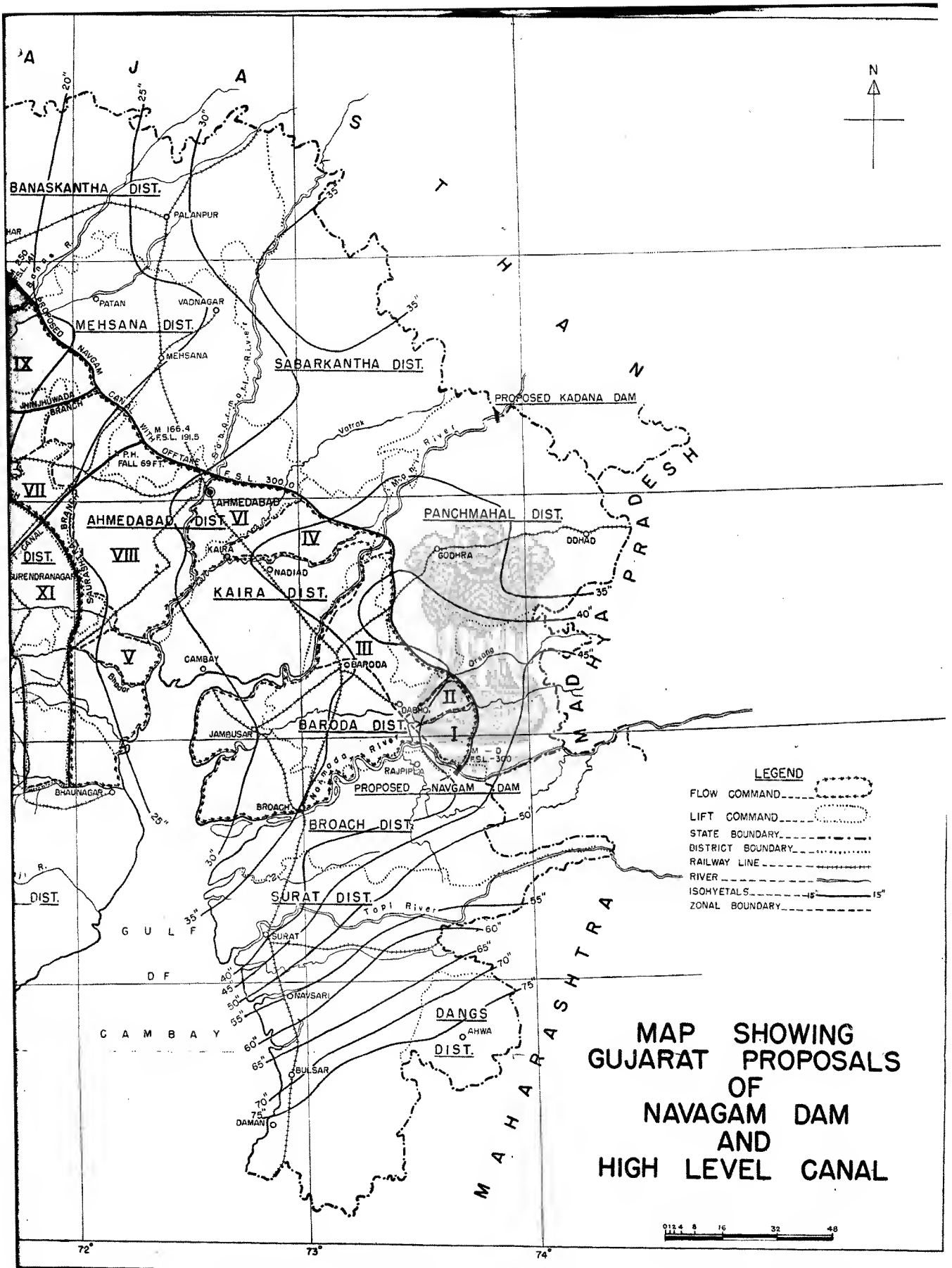
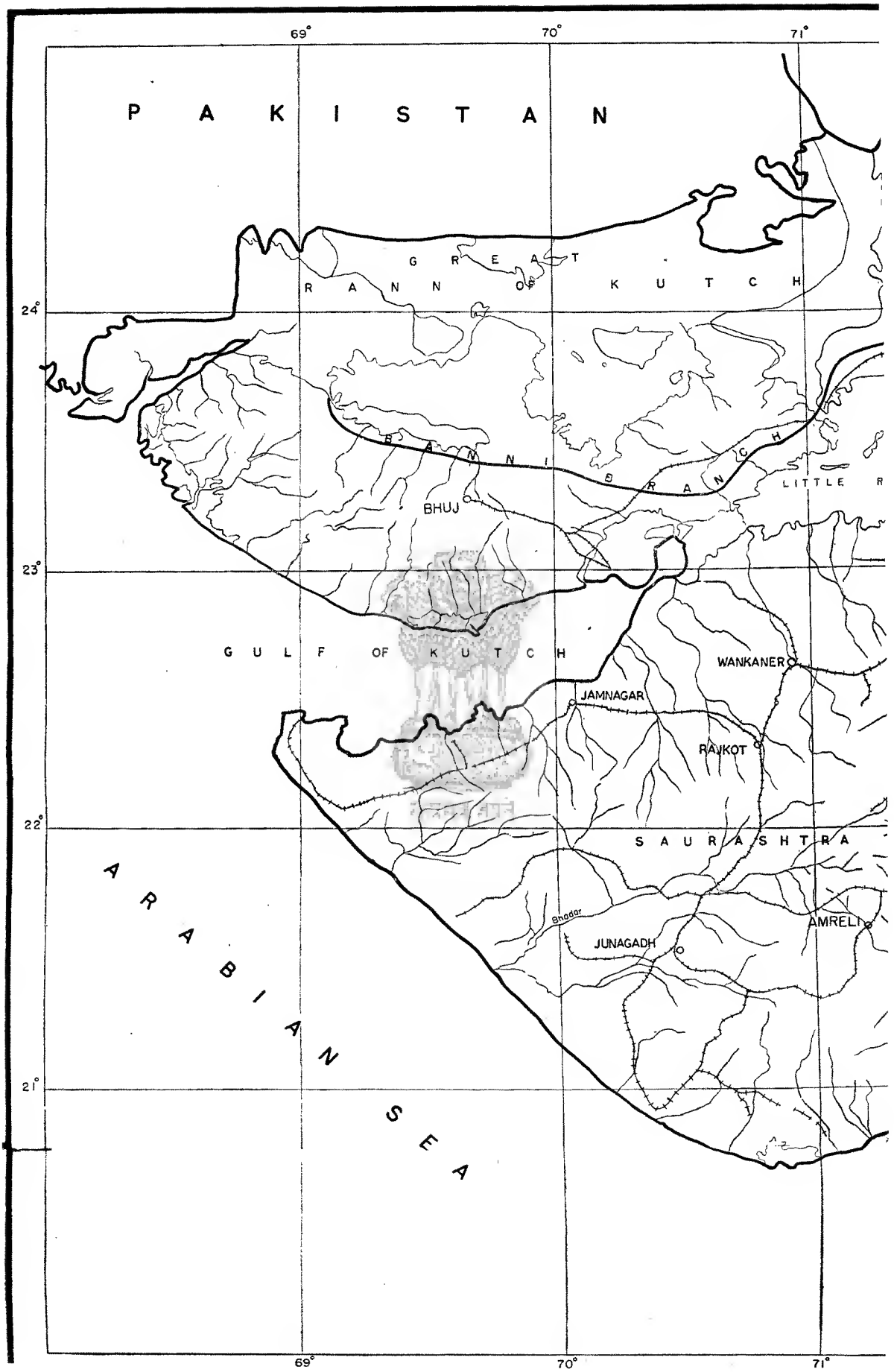


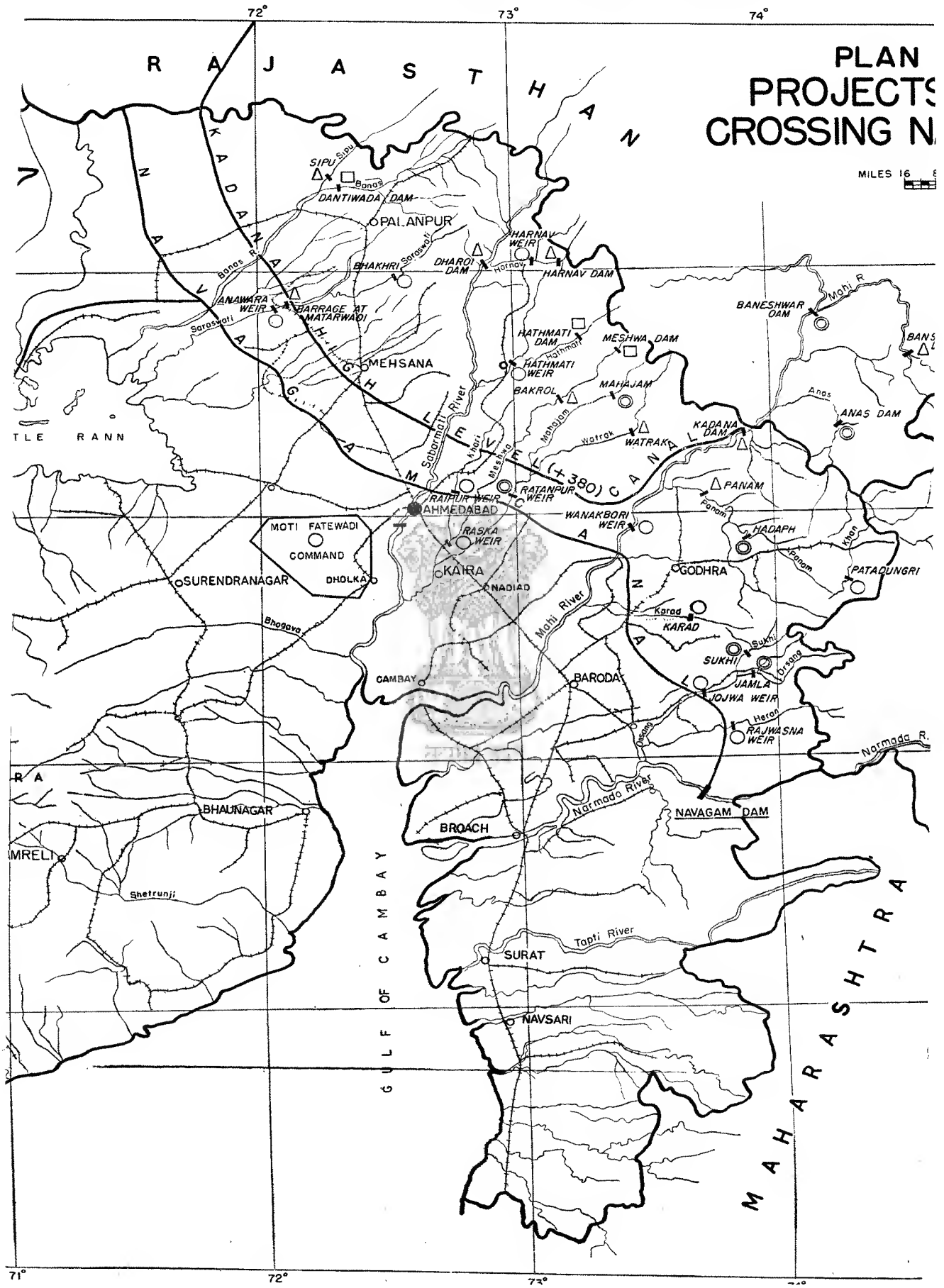
PLATE VI-2


MAHANADI BASIN)
BURHNER T. R. L. 1570
R.L. 2025
Burhner
F.R.L. 1700
F.R.L. 1764
F.R.L. 1515
F.R.L. 1363
1150
F.R.L. 2160
F.R.L. 2480
3600
3200
2800
2400
2000
1600
1200
800
400
0
1208
1360
1515
1980
1185
BARGI
BASANIA
ROSRA
RAGHAVPUR
UPPER NARMADA (R.H. IN MAHANADI BASIN) SOURCE
1203
1450
1505
1970
2400
3468
235
156
138
84
28
0


69°
70°
71°
WEST PAKISTAN
GREAT RANN OF KUTCH
LITTLE RANN
BANNI BRANCH CANAL
KUTCH DIST.
BHUJ
BHACHAU
LIFT CANAL
XI
MANDVI
KANDLA
GULF OF KUTCH
OKHA
JAMNAGAR
JAMNAGAR DIST.
MORVI
WANKANER
SURENDRANAGAR
RAJKOT
RAJKOT DIST.
PORBANDAR
JUNAGADH
JUNAGARH DIST.
AMRELI
AMRELI DIST.
VERAVAL
ARABIAN SEA
X
SANTALPUR
RADHANPUR
DHRANGADHRA
KANDLA BRANCH CANAL
BHAVNAGAR
M—294
FSL—100
10°
15°
20°
25°
30°
24°
23°
22°
21°

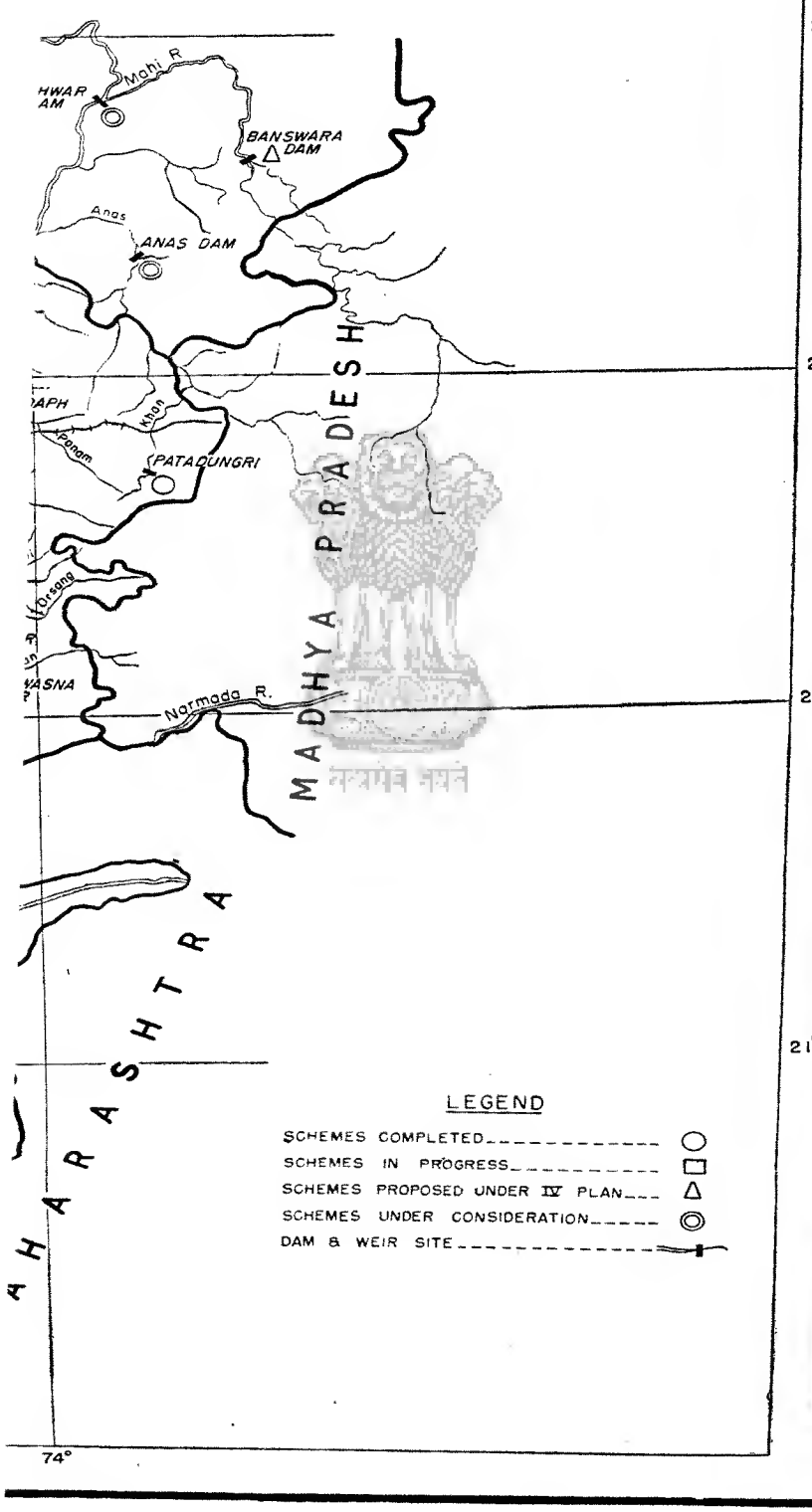

BANASKANTHA DIST.
PALANPUR
PATAN
VADNAGAR
MEHSANA DIST.
MEHSANA
SABARKANTHA DIST.
PROPOSED KADANA DAM
PROPOSED NAVGAM CANAL
JHINJHUWADA BRANCH CANAL
M 166.4 WITH F.S.L. 191.5
P.H. FALL 69 FT.
OFFTAKE F S L 300/0
AHMEDABAD
AHMEDABAD DIST.
PANCHMAHAL DIST.
GODHRA
DOHAD
KAIRA
NADIAD
KAIRA DIST.
SURENDRANAGAR DIST.
SAURASHTRA CANAL
CAMBAY
BARODA
DABHOI
JAMBUSAR
BARODA DIST.
RAJPIPLA
PROPOSED NAVGAM DAM
BROACH
BROACH DIST.
BHAUNAGAR
SURAT DIST.
Tapi River
SURAT
NAVSARI
DANGS DIST.
AHWA
BULSAR
DAMAN
GULF OF CAMBAY
MADHYA PRADESH
MAHARASHTRA
N
LEGEND
FLOW COMMAND
LIFT COMMAND
STATE BOUNDARY
DISTRICT BOUNDARY
RAILWAY LINE
RIVER
ISOHYETALS
ZONAL BOUNDARY
MAP SHOWING GUJARAT PROPOSALS OF NAVAGAM DAM AND HIGH LEVEL CANAL
72°
73°
74°

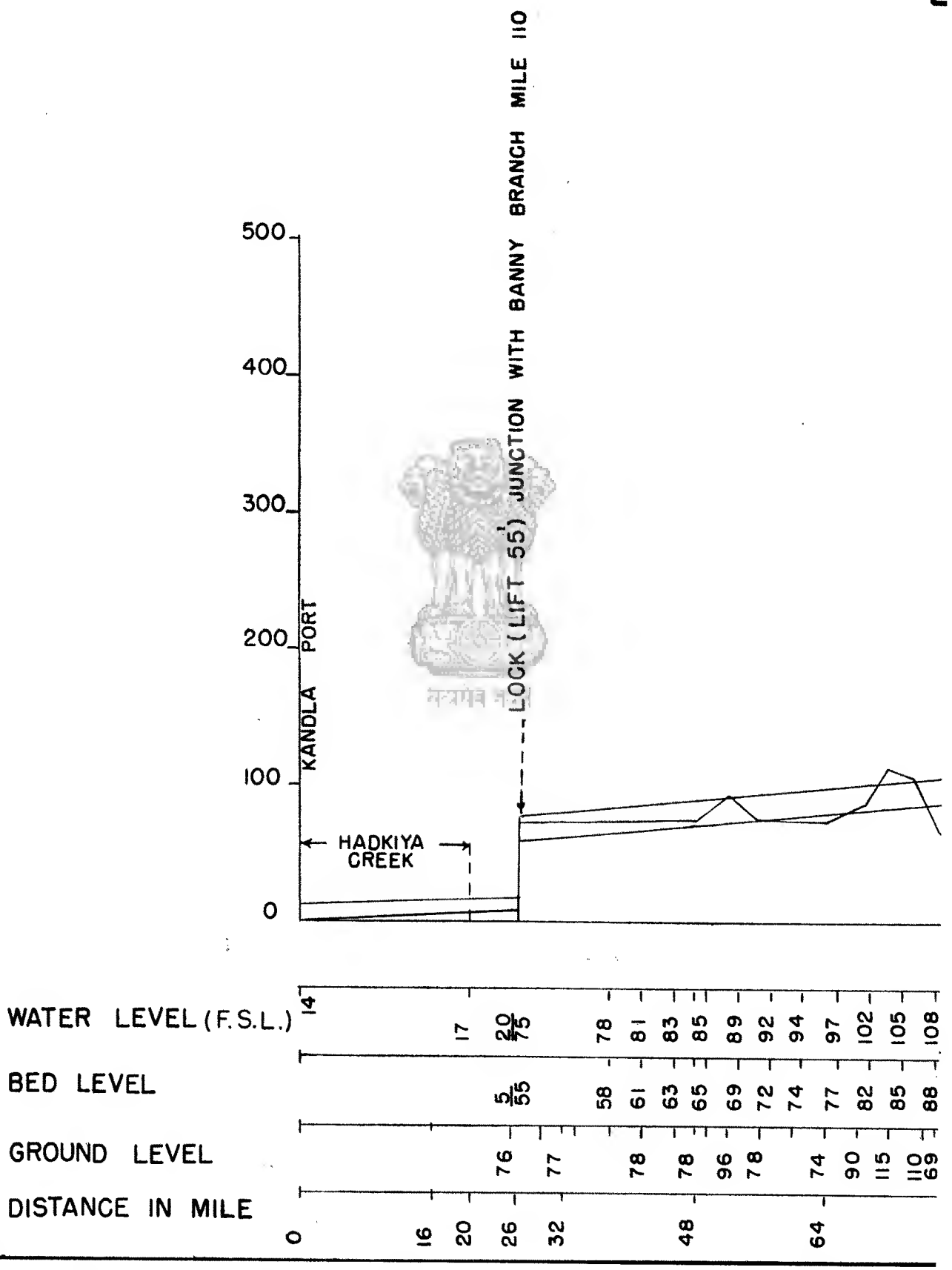

69°
70°
71°
PAKISTAN
GREAT RANN OF KUTCH
24°
BANNI BRANCH
LITTLE R
BHUJ
23°
GULF OF KUTCH
WANKANER
JAMNAGAR
RAJKOT
22°
SAURASHTRA
ARABIAN SEA
Bhadar
AMRELI
JUNAGADH
21°
69°
70°
71°


PLAN
PROJECTS
CROSSING N
MILES 16
72°
73°
74°
71°
RAJASTHAN
MAHARASHTRA
GULF OF CAMBAY
SIPU
Sipu
Banas
DANTIWADA DAM
PALANPUR
HARNAV WEIR
HARNAV DAM
DHAROI DAM
Harnav
BHAKHRI
Saraswati
Banas R.
ANAWARA WEIR
BARRAGE AT MATARWADI
Saraswati
MEHSANA
HATHMATI DAM
HATHMATI WEIR
Hathmati
MESHWA DAM
BANESHWAR DAM
Mohi R.
BAKROL
MAHAJAM
Anas
ANAS DAM
KADANA DAM
WATRAK
Watrak
Mahajam
Meshwa
Anari
Sabarmati River
SABARMATI (+380) CANAL
RATANPUR WEIR
RATNPUR WEIR
AHMEDABAD
PANAM
Panam
WANAKBORI WEIR
MOTI FATEWADI
COMMAND
DHOLKA
RASKA WEIR
KAIRA
NADIAD
SURENDRANAGAR
Bhogava
Mohi River
HADAPH
Khan
Panam
GODHRA
PATADUNGRI
Karad
KARAD
Sukhi
SUKHI
Dhasana
JAMLA
JOJWA WEIR
CAMBAY
BARODA
Heran
RAJWASNA WEIR
Dhasana
Narmada R.
Narmada River
NAVAGAM DAM
BHAUNAGAR
BROACH
MRELI
Shetrunji
Tapti River
SURAT
NAVSARI

PLAN SHOWING
ROJECTS ON RIVERS
)SSING NAVAGAM CANAL

MILES 16 8 0 16 32 MILES

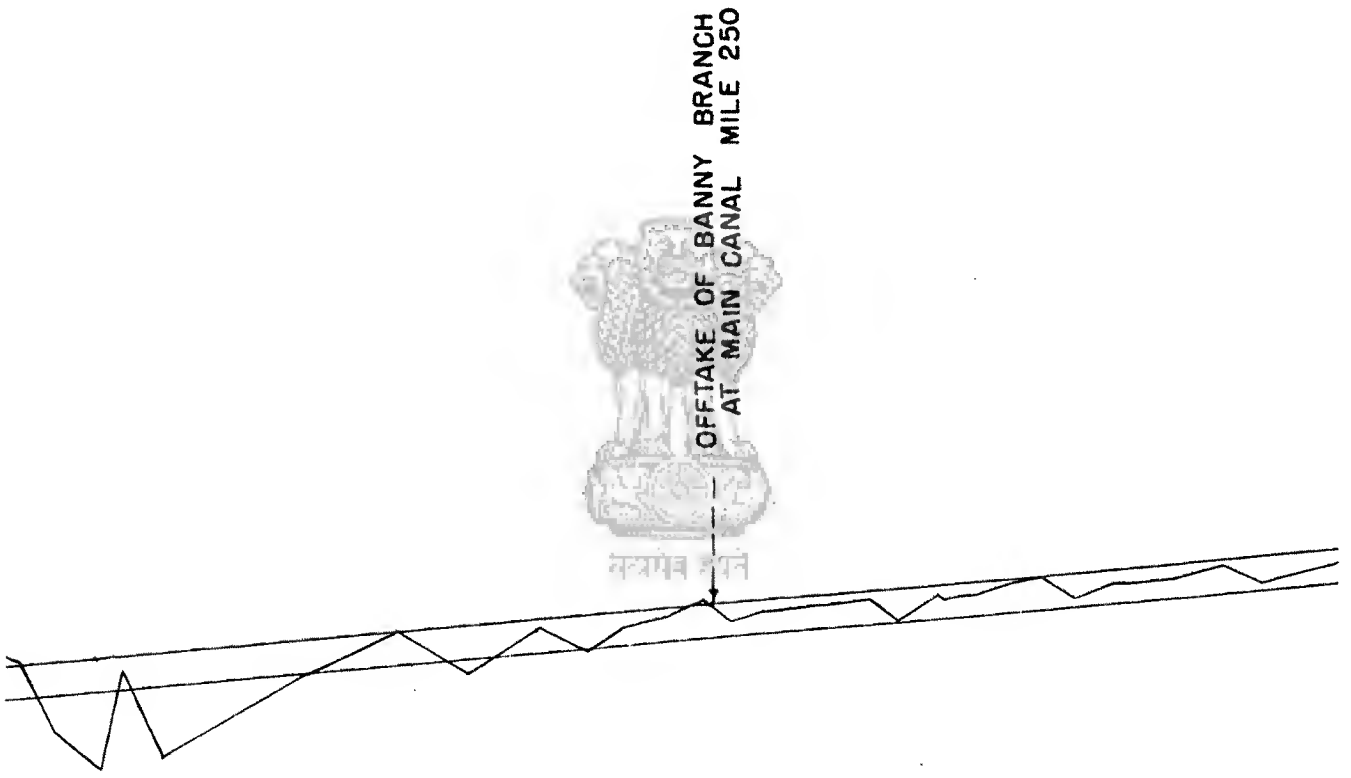


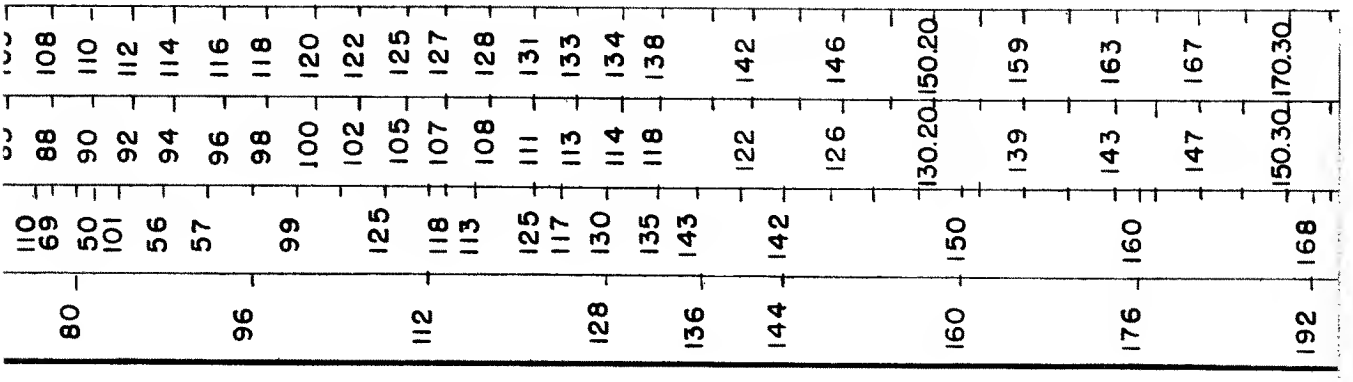

KANDLA PORT
HADKIYA CREEK
LOCK (LIFT 55') JUNCTION WITH BANNY BRANCH MILE 110
500
400
300
200
100
0
WATER LEVEL (F.S.L.)
BED LEVEL
GROUND LEVEL
DISTANCE IN MILE
14
17
20/75
78
81
83
85
89
92
94
97
102
105
108
5/55
58
61
63
65
69
72
74
77
82
85
88
76
77
78
78
96
78
74
90
115
110
69
0
16
20
26
32
48
64

L. SECTION OF NAVIGATION LINI

FROM KANDLA PORT TO NAVAGAM RESERVOIR

SCALE :— VER. – 1" = 100 FT.
HOR. 1" = 16 MILES





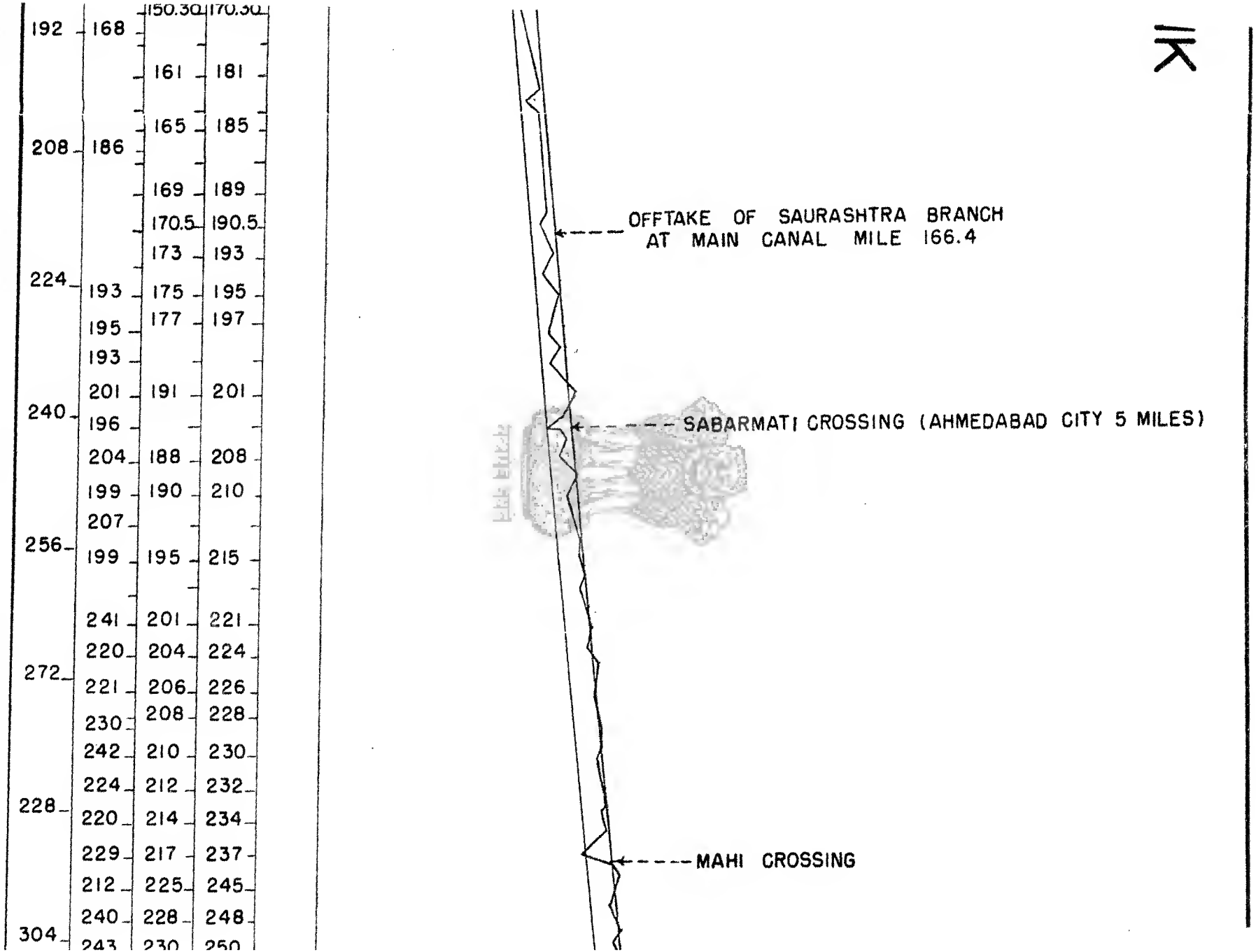
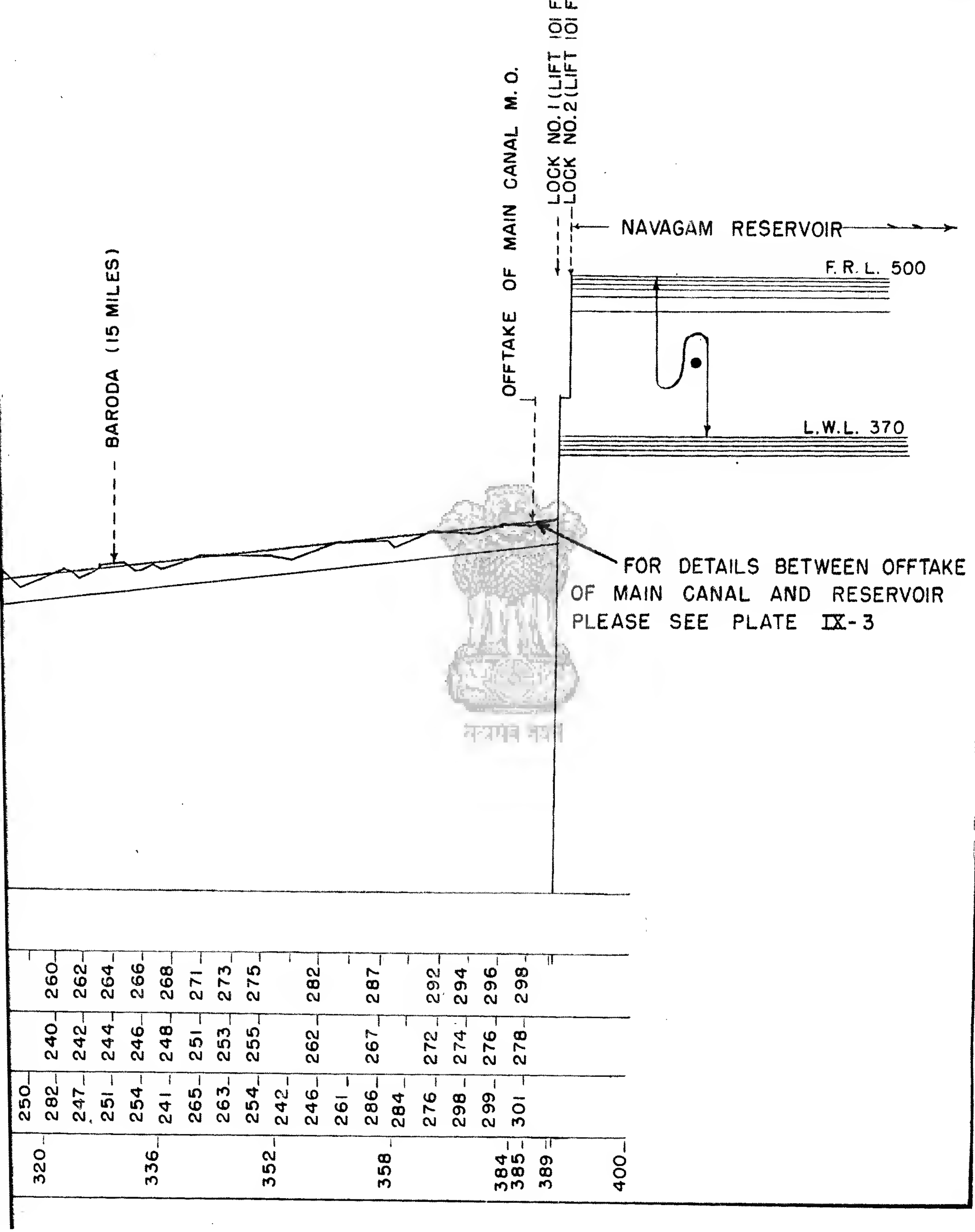
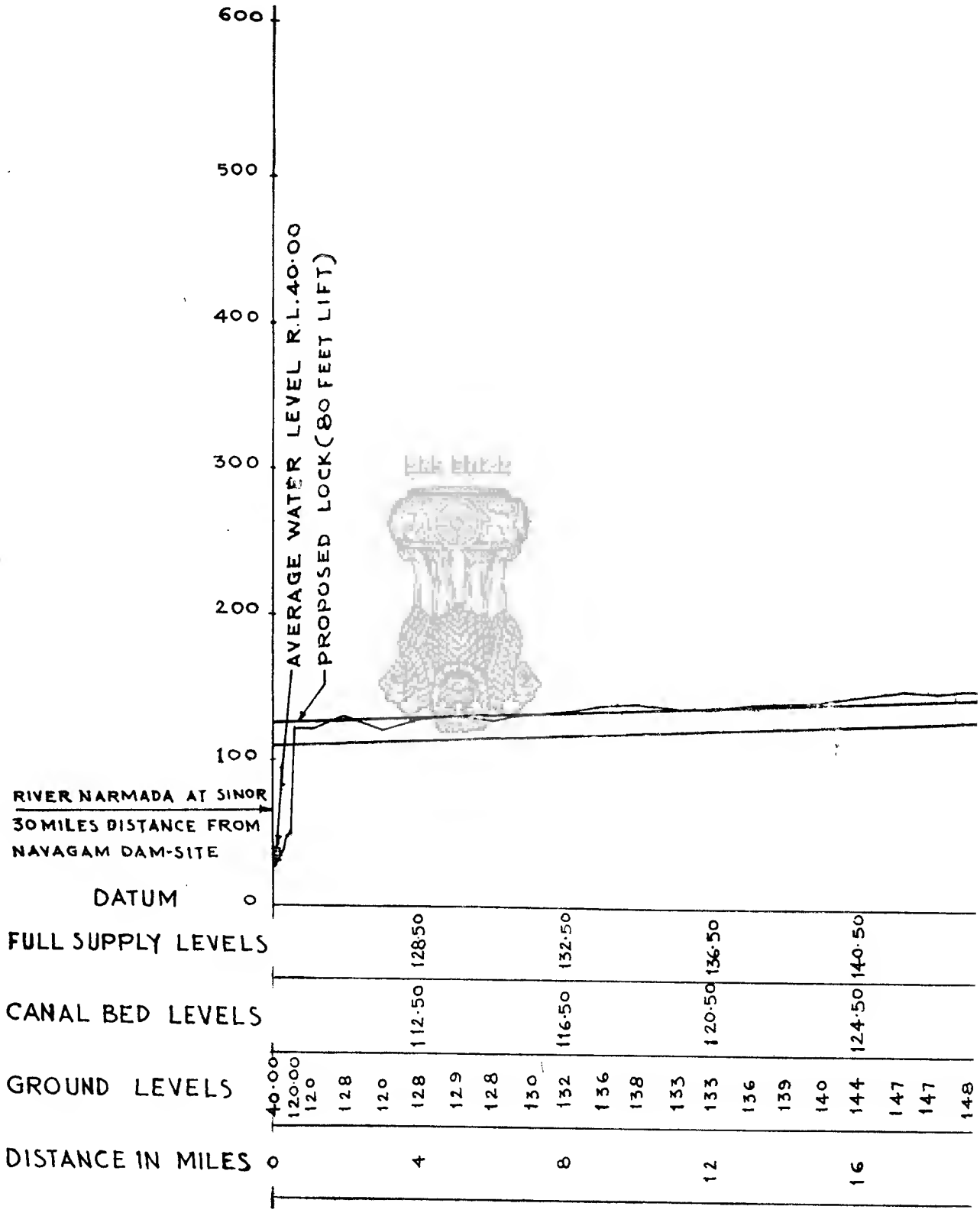

150.30
170.30
192
168
161
181
165
185
208
186
169
189
170.5
190.5
173
193
224
193
175
195
195
177
197
193
201
191
201
240
196
204
188
208
199
190
210
207
256
199
195
215
241
201
221
220
204
224
272
221
206
226
230
208
228
242
210
230
224
212
232
228
220
214
234
229
217
237
212
225
245
240
228
248
304
243
230
250
OFFTAKE OF SAURASHTRA BRANCH
AT MAIN CANAL MILE 166.4
SABARMATI CROSSING (AHMEDABAD CITY 5 MILES)
MAHI CROSSING
K

PLATE IX-2



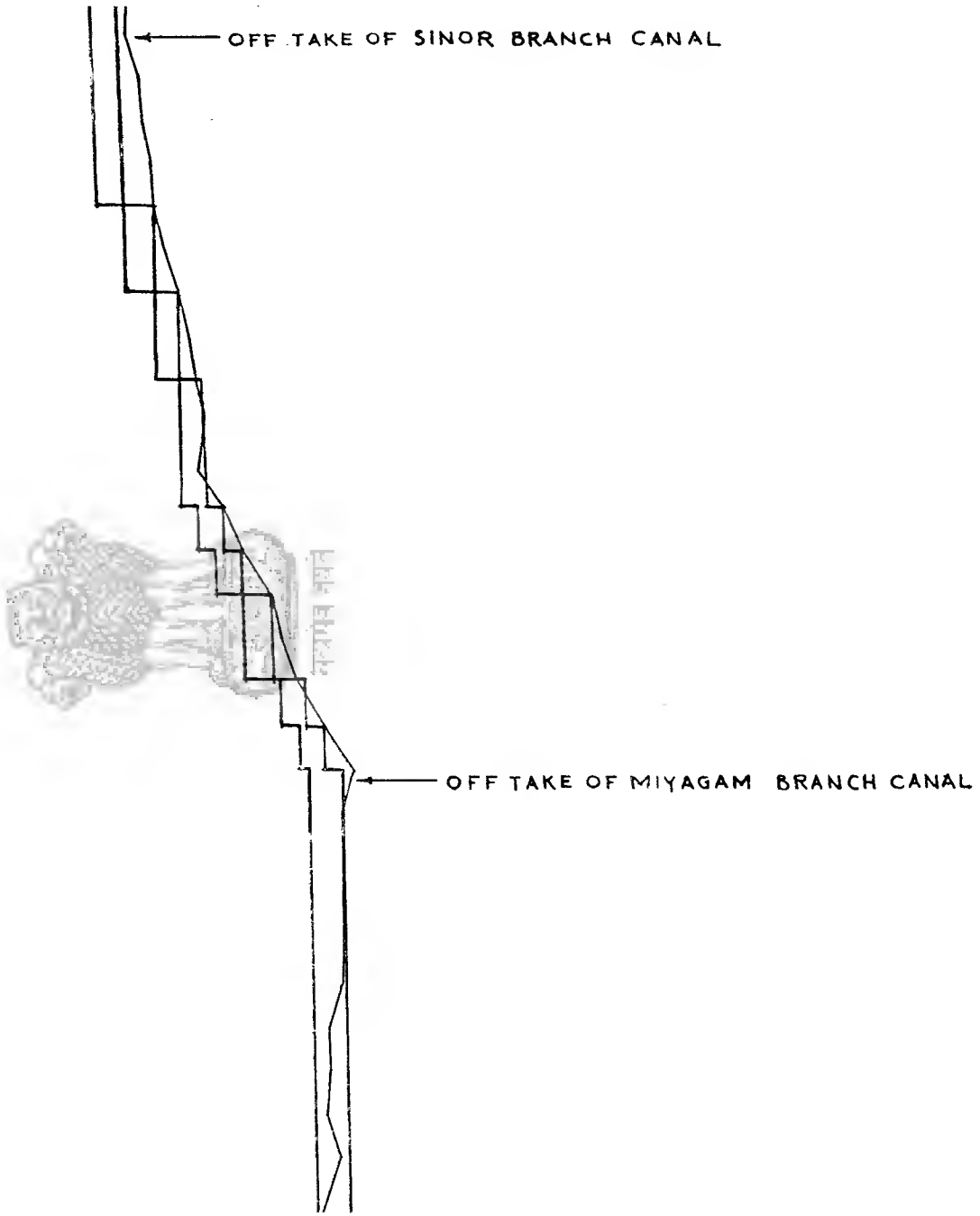
LOCK NO. 1 (LIFT 101 FT.)
LOCK NO. 2 (LIFT 101 FT.)
OFFTAKE OF MAIN CANAL M. O.
NAVAGAM RESERVOIR
F. R. L. 500
L. W. L. 370
BARODA (15 MILES)
FOR DETAILS BETWEEN OFFTAKE OF MAIN CANAL AND RESERVOIR PLEASE SEE PLATE IX-3
260 262 264 266 268 271 273 275 282 287 292 294 296 298
240 242 244 246 248 251 253 255 262 267 272 274 276 278
250 282 247 251 254 241 265 263 254 242 246 261 286 284 276 298 299 301
320 336 352 358 384 385 389 400


600
500
400
300
200
100
AVERAGE WATER LEVEL R.L.40·00
PROPOSED LOCK (80 FEET LIFT)
RIVER NARMADA AT SINOR
30 MILES DISTANCE FROM
NAVAGAM DAM-SITE
DATUM 0
FULL SUPPLY LEVELS
128·50
132·50
136·50
140·50
CANAL BED LEVELS
112·50
116·50
120·50
124·50
GROUND LEVELS
40·00
120·00
120
128
120
128
129
128
130
132
136
138
133
133
136
139
140
144
147
147
148
DISTANCE IN MILES
0
4
8
12
16

TRCD BY : Sane

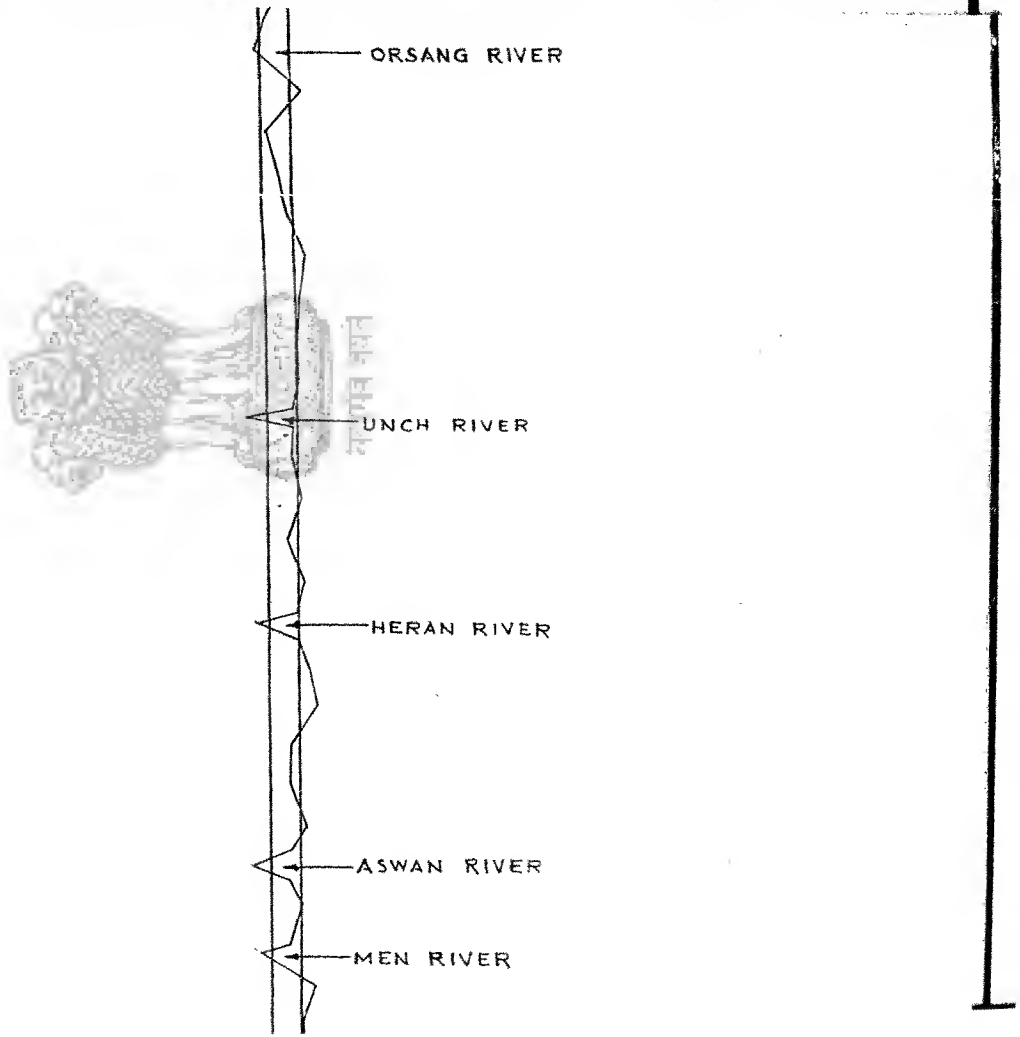
20	149	128·50	144·50
	156		
	158		
	161		
24	162	131·00	147·00
		146·00	162·00
	170		
	179	147·25	163·25
		162·25	178·25
	184		
28	189	163·50	179·50
		178·50	194·50
	194		
	190		
	205	180·37	196·37
		190·37	206·37
32	217	191·00	207·00
		201·00	217·00
	232	201·62	217·62
		216·62	232·62
	239		
	249	217·87	233·87
		237·87	253·87
36	263	238·50	254·50
		248·50	264·50
	280	249·12	266·12
		255·50	275·50
	272		
	273		
40	273	257·00	277·00
	274		
	273		
	267		
44	268	259·00	279·00
	266		
	272		

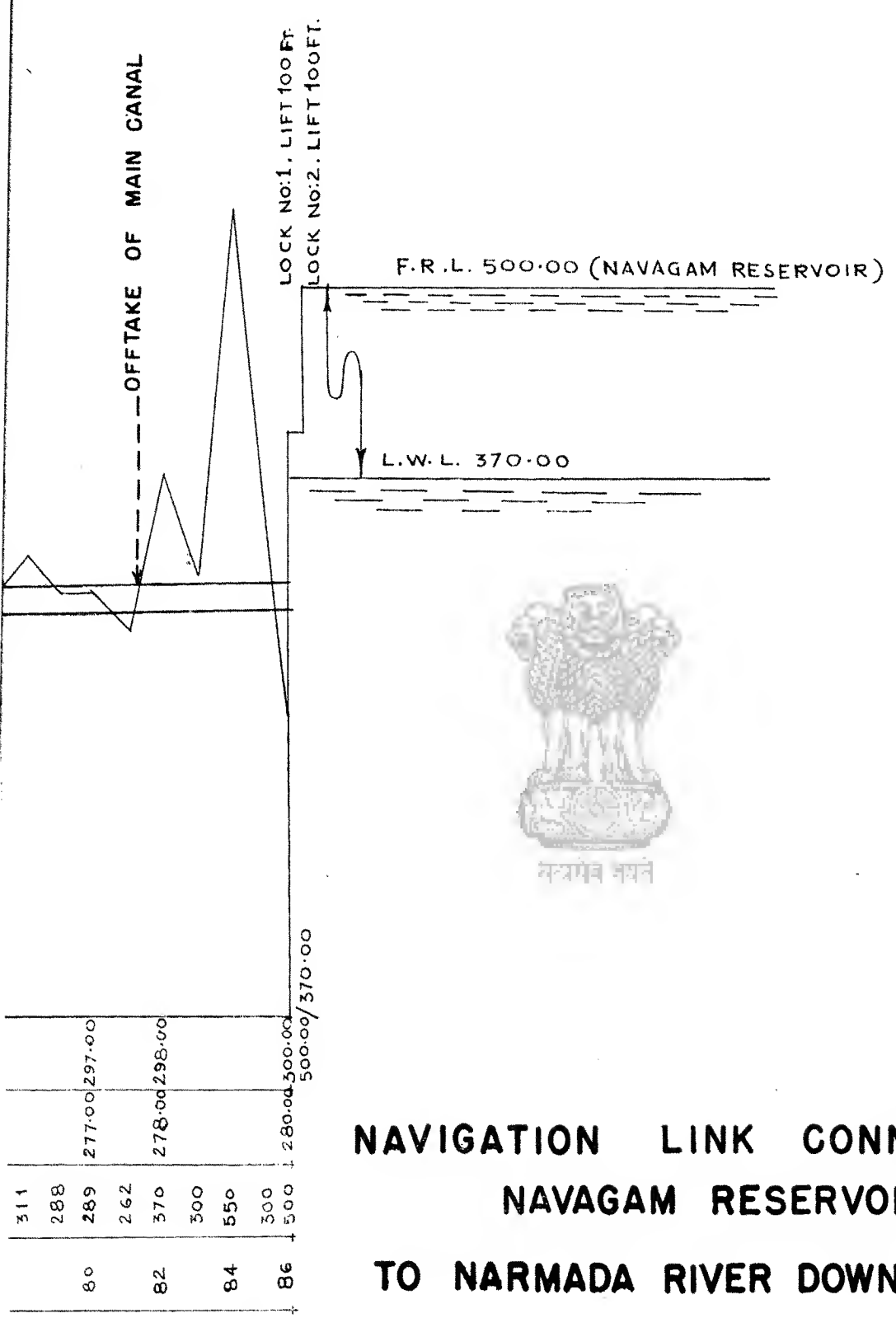
SCALE :- HOR. 1"=4
VER. 1"=



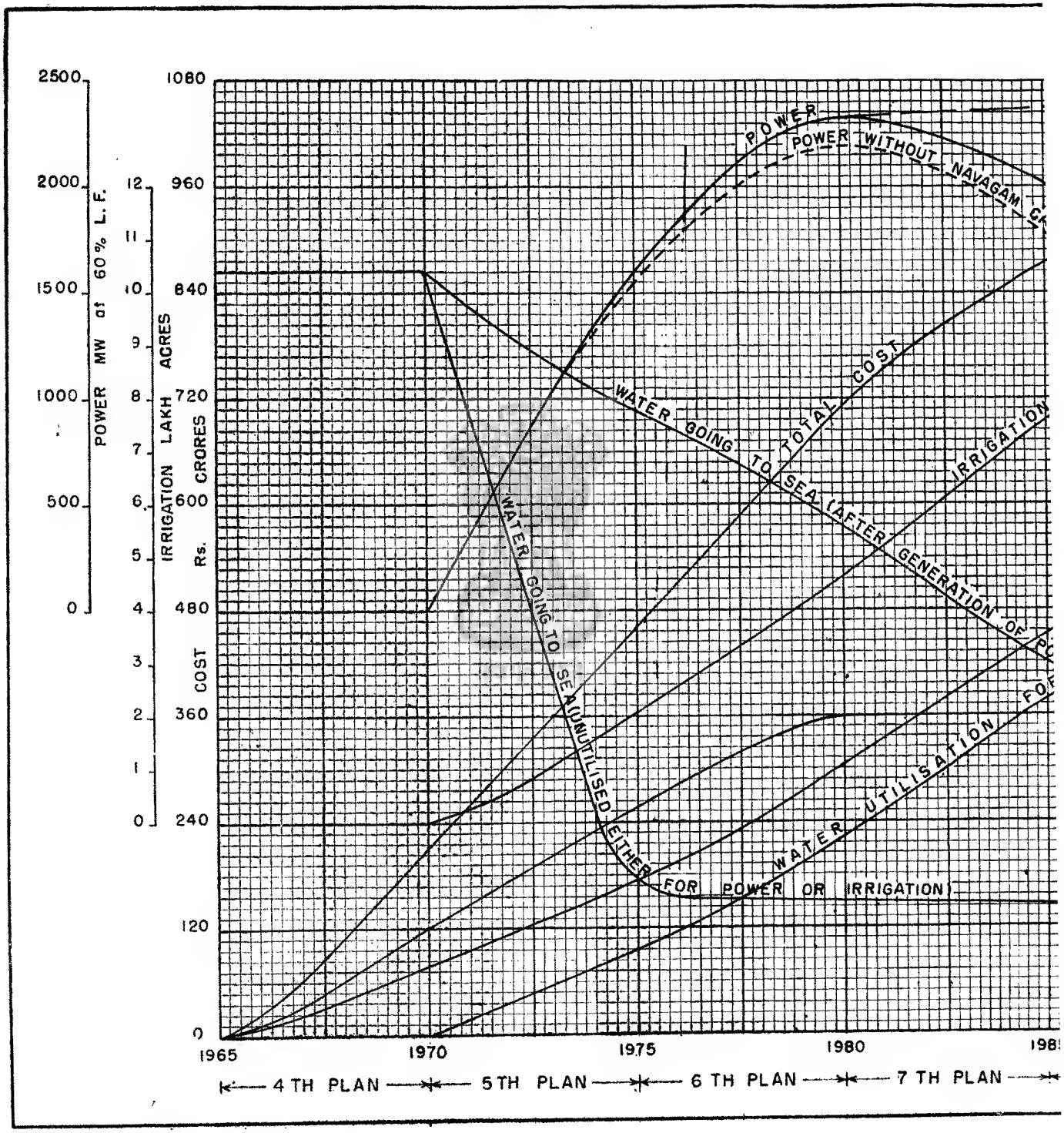
4 MILES
100 FEET.

48	257	261·00	281·00
	287		
	265		
	271		
52	278	263·00	283·00
	289		
	283		
	281		
56	283	265·00	285·00
	280		
	251		
	280		
	286		
60	277	267·00	287·00
	288		
	281		
	257		
	290		
64	297	269·00	289·00
	280		
	280		
	290		
68	261	271·00	291·00
	289		
	281		
	263		
	298		
72	290	273·00	293·00
	291·		

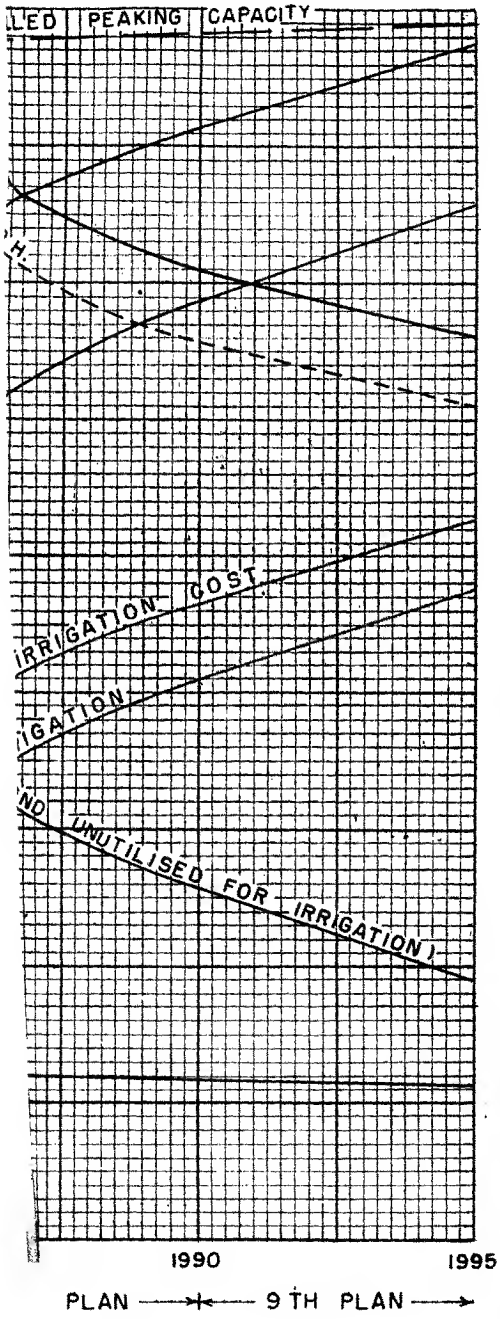


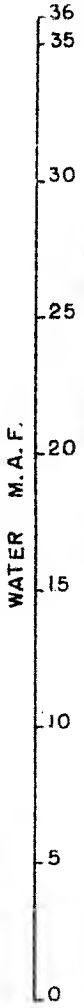


NAVIGATION LINK CONNECTING NAVAGAM RESERVOIR TO NARMADA RIVER DOWN BELOW


2500
2000
1500
1000
500
0
POWER MW at 60% L.F.
1080
960
840
720
600
480
360
240
120
0
IRRIGATION LAKH ACRES
COST Rs. CRORES
12
11
10
9
8
7
6
5
4
3
2
1
0
POWER
POWER WITHOUT NAVAGAM
WATER GOING TO TOTAL COST
IRRIGATION
WATER GOING TO SEA (AFTER GENERATION OF
WATER GOING TO SEA (UNUTILISED EITHER FOR POWER OR IRRIGATION)
WATER UTILISATION
1965
1970
1975
1980
4 TH PLAN
5TH PLAN
6 TH PLAN
7 TH PLAN

PHASING OF NARMADA BASIN DEVELOPMENT
(WITH NAVAGAM + 500)





	4 th PLAN	5 th PLAN	6 th PLAN	7 th PLAN	8 th PLAN	9 th PLAN
IRRIGATION (Lakh acres)	—	20.5	46.1	76.1	96.9	111.9
WATER UTILISATION For irrigation M.A.F.	—	4.1	9.3	15.75	20.5	23.8
WATER GOING TO SEA						
i) After generation of power and unutilised for irrigation. M.A.F.	36	29.4	24.0	17.55	12.8	9.5
ii) Unutilised either for irrigation or power M.A.F.	36	7.15	6.11	6.02	5.95	5.60
POWER MW at 60 % L.F.	—	1608	2338	2014	1539	1304
COST Rs. Crores						
i) Irrigation	80.2	175.5	303.5	453.5	555.5	631.5
ii) Power	121	255	358	358	358	358
iii) Grand Total (including navigation)	211.2	460.5	711.5	871.5	973.5	1050

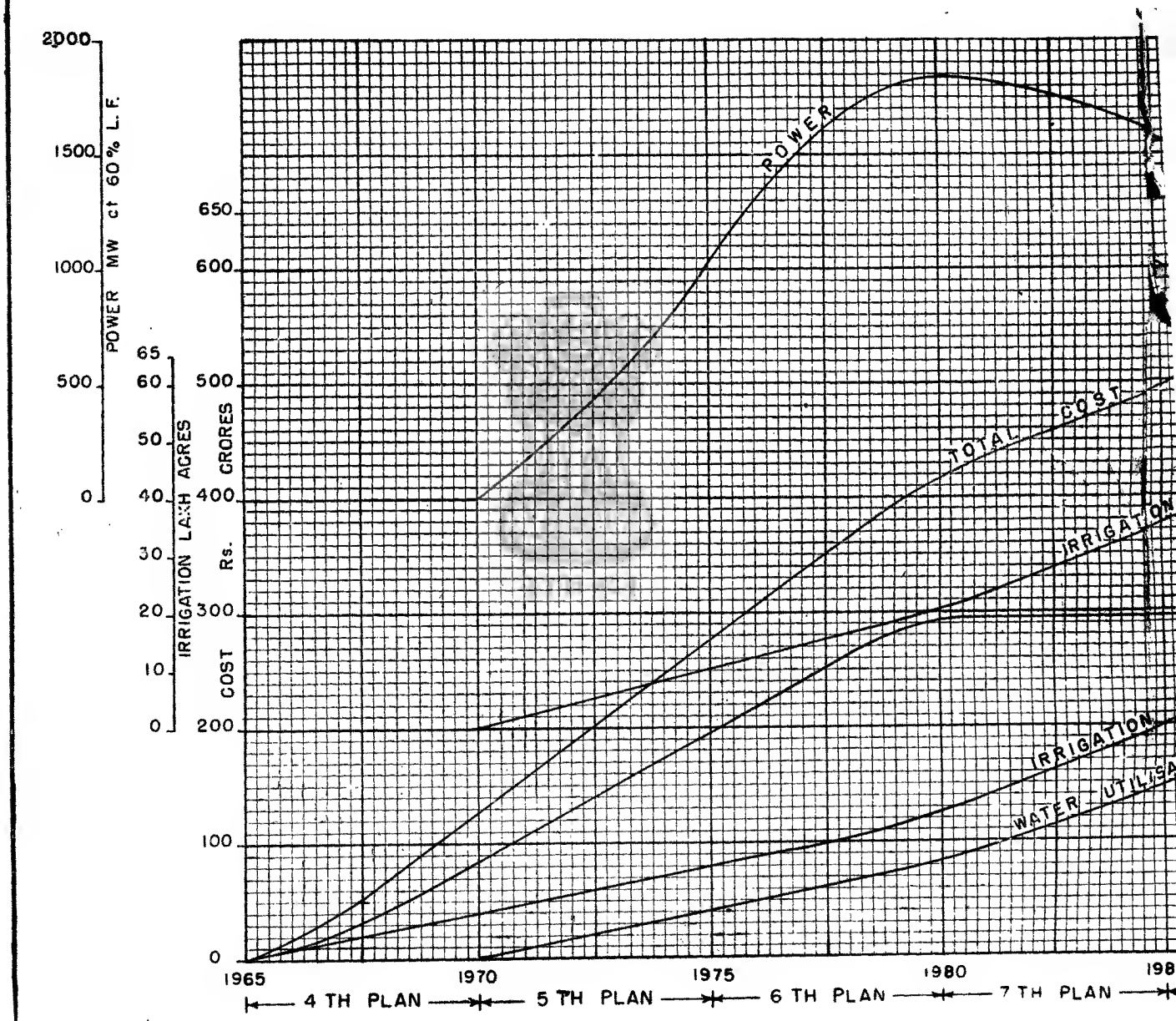
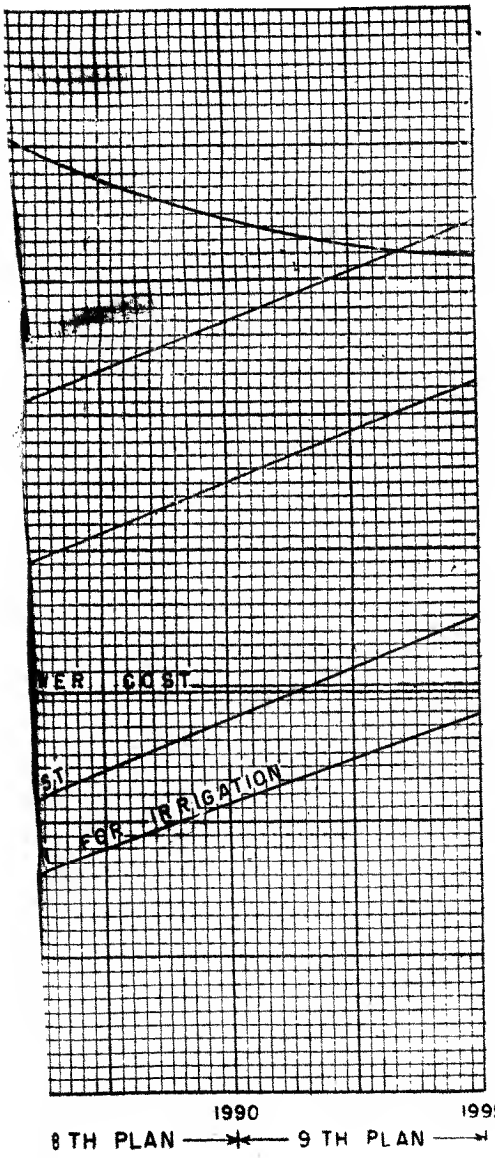
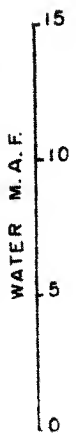

2000
1500
1000
500
0
POWER MW at 60% L.F.
65
60
50
40
30
20
10
0
IRRIGATION LAKH ACRES
650
600
500
400
300
200
100
0
COST Rs. CRORES
POWER
TOTAL COST
IRRIGATION
IRRIGATION
WATER UTIL'SA
1965
1970
1975
1980
198
4 TH PLAN
5 TH PLAN
6 TH PLAN
7 TH PLAN

PLATE XI-2

PHASING OF NARMADA DEVELOPMENT IN MADHYA PRADESH





	4 th PLAN	5 th PLAN	6 th PLAN	7 th PLAN	8 th PLAN	9 th PLAN
IRRIGATION (Lakh acres)	–	10	20	35	50	65
WATER UTILISATION For irrigation M.A.F.	–	2	4	7.25	10.50	13.80
POWER MW at 60% L.F.	–	1042	1832	1592	1229	1076
COST Rs. Crores						
i) Irrigation	40	80	125	200	275	351
ii) Power	85	195	292	292	292	292
iii) Grand Total	125	275	417	492	567	643

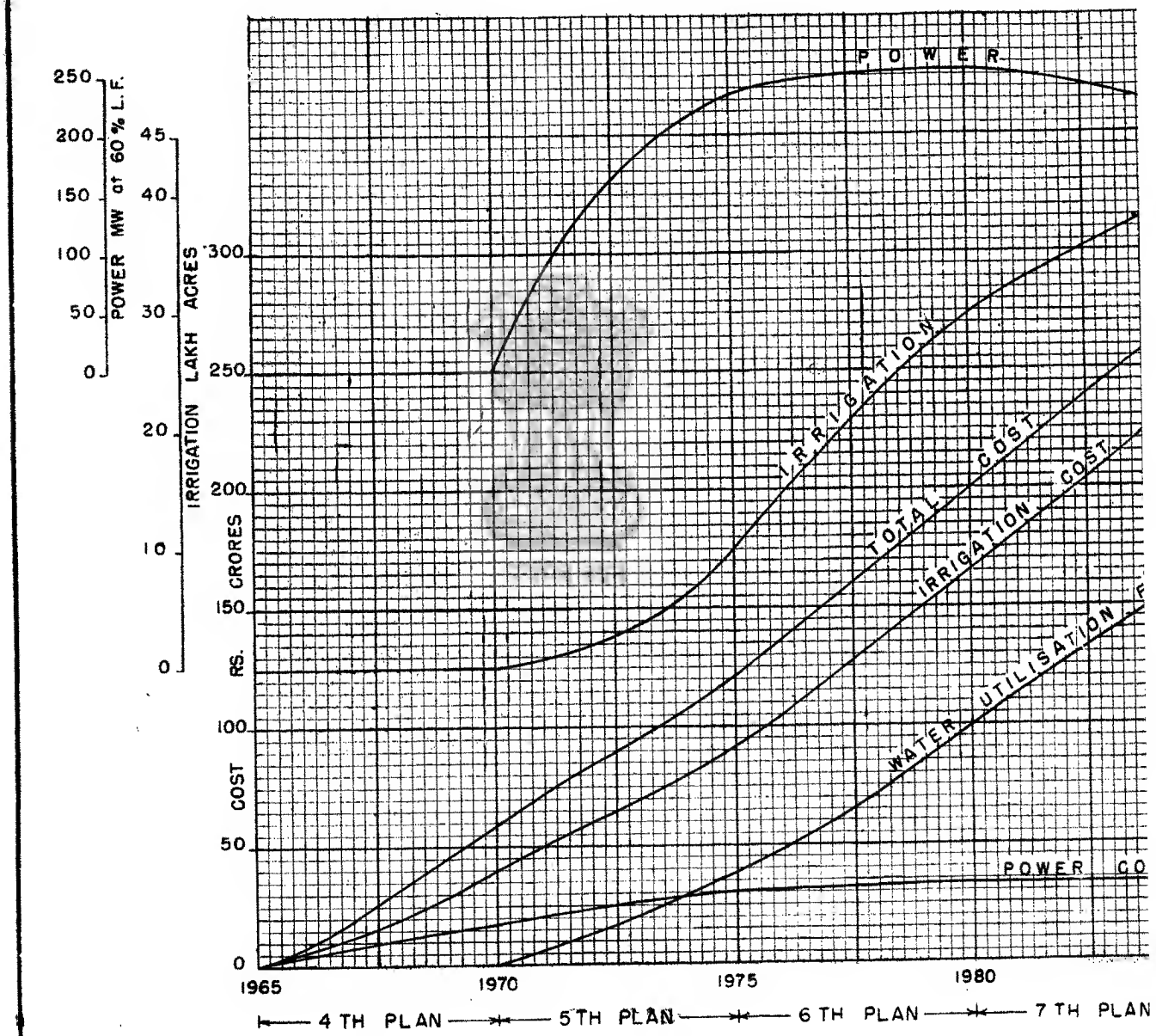
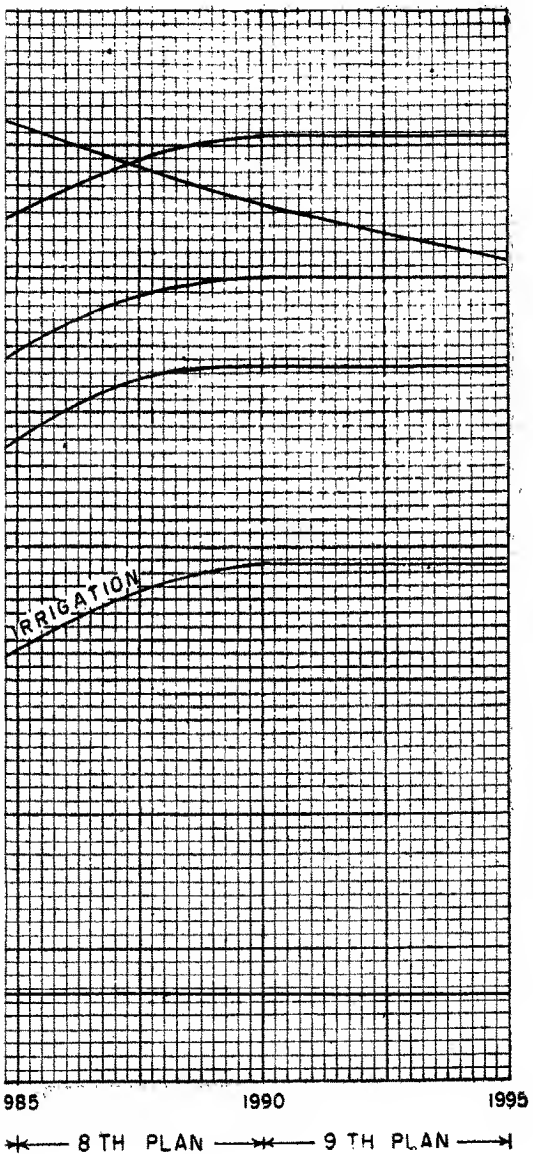
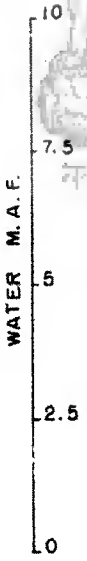

POWER MW at 60% L.F.
250
200
150
100
50
0
IRRIGATION LAKH ACRES
45
40
30
20
10
0
COST RS. CRORES
300
250
200
150
100
50
0
1965
1970
1975
1980
4 TH PLAN
5TH PLAN
6 TH PLAN
7 TH PLAN
POWER
IRRIGATION
TOTAL COST
IRRIGATION COST
WATER UTILISATION
POWER CO

PLATE XI-3

PHASING OF NARMADA DEVELOPMENT IN GUJARAT



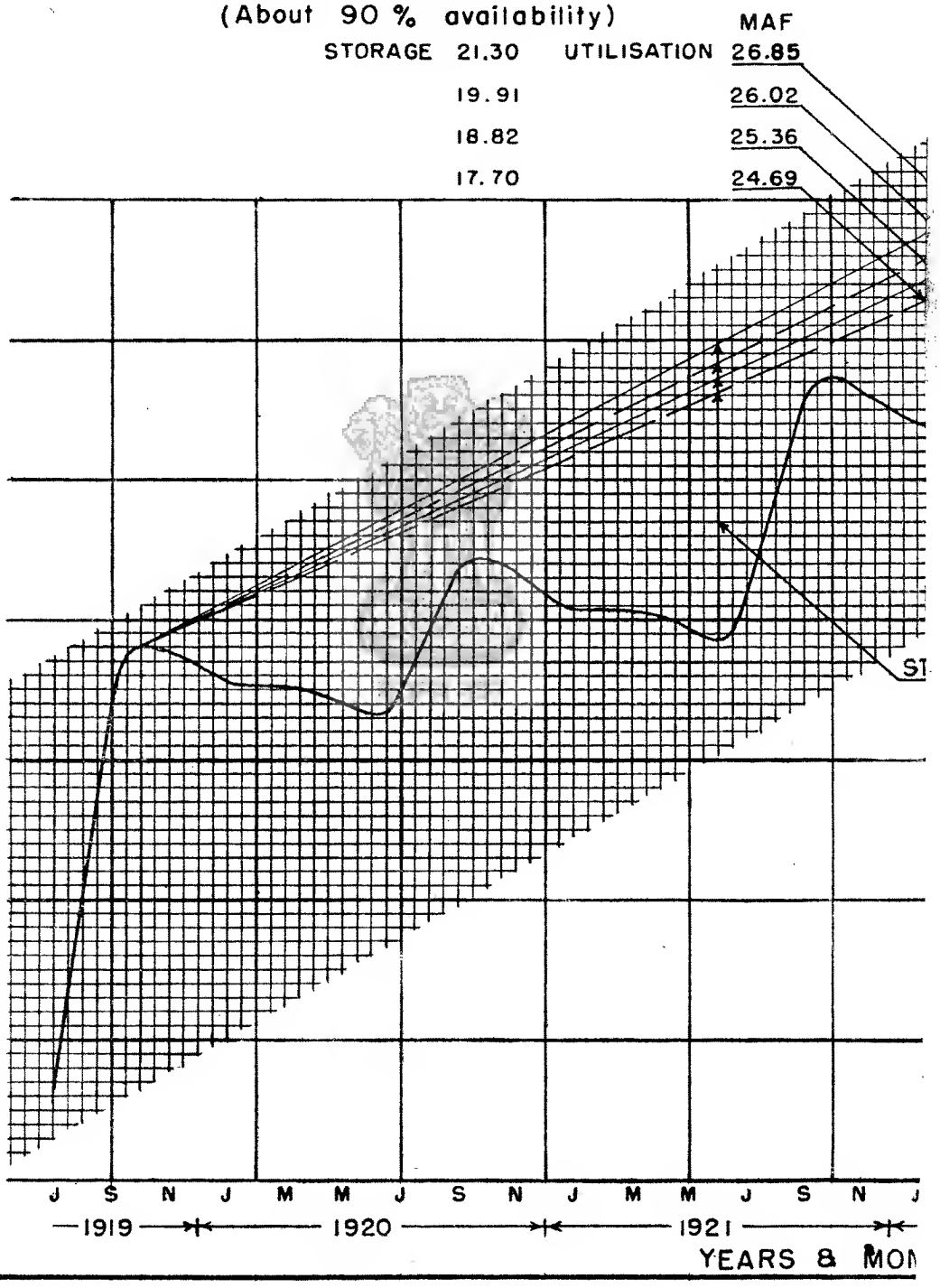
	4 th PLAN	5 th PLAN	6 th PLAN	7 th PLAN	8 th PLAN	9 th PLAN
IRRIGATION (Lakh acres)	–	10	25	40	45.8	45.8
WATER UTILISATION For Irrigation M A.F.	—	1.9	4.95	8.15	9.65	9.65
POWER MW at 60 % L.F.	—	234	253	211	155	114
COST Rs. Crores i) Irrigation	40	90	165	240	267	267
ii) Power	18	30	33	33	33	33
iii) Grand Total	58	120	198	273	300	300



NARMADA AT HIRANPHAL

MASS CURVE FOR CRITICAL CYCLE

Allowing for 13.80 MAF (including 1.92 MAF of minor schemes) of irrigation abstraction (About 90 % availability)



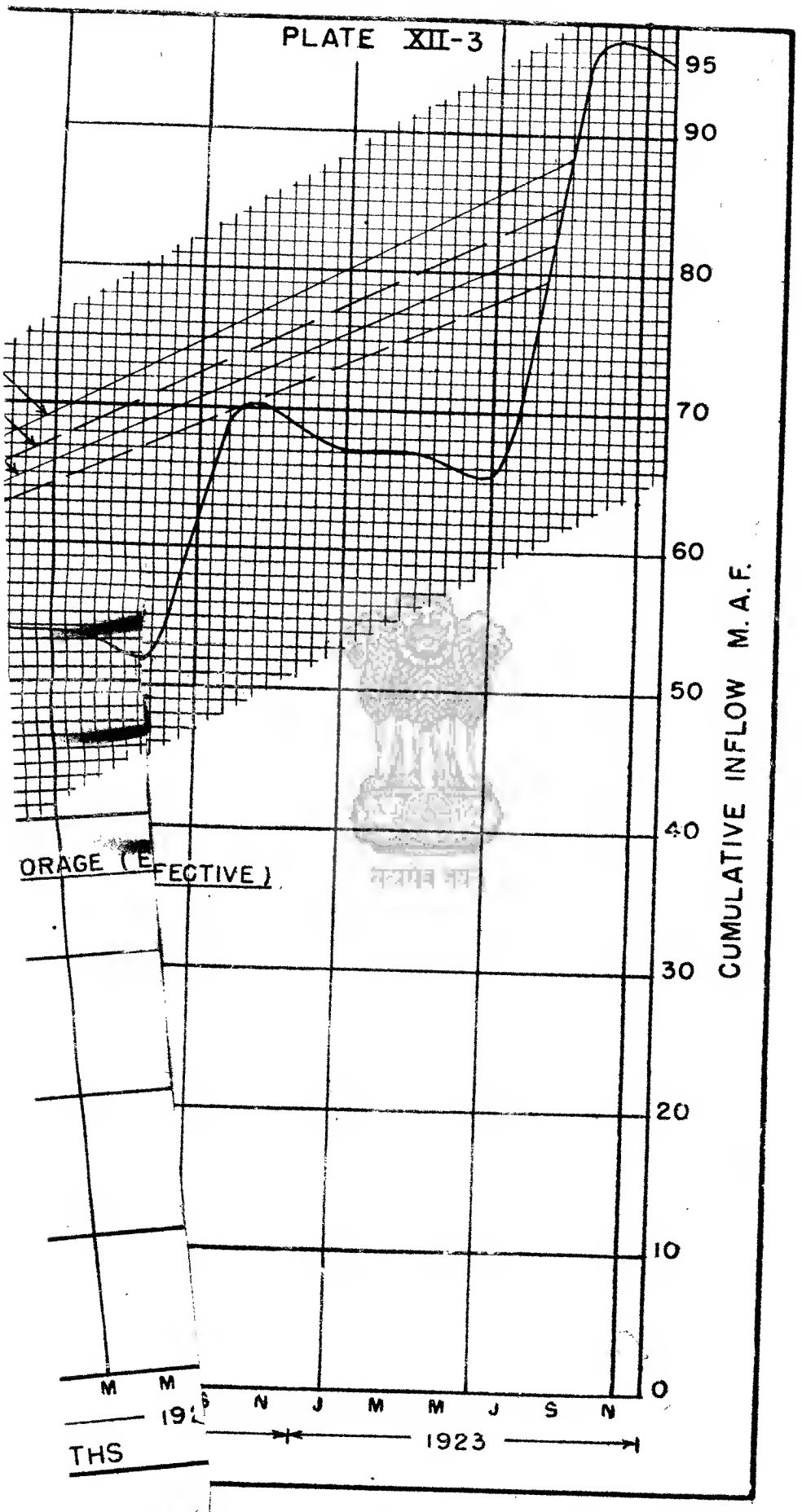


PLATE XII-3
95
90
80
70
60
50
40
30
20
10
0
CUMULATIVE INFLOW M.A.F.
ORAGE (EFFECTIVE)
M
M
N
J
M
M
J
S
N
1923
THS

NARMADA A

MASS CURVE FOR

Allowing for 23.80 MAF
minor schemes) of irrig

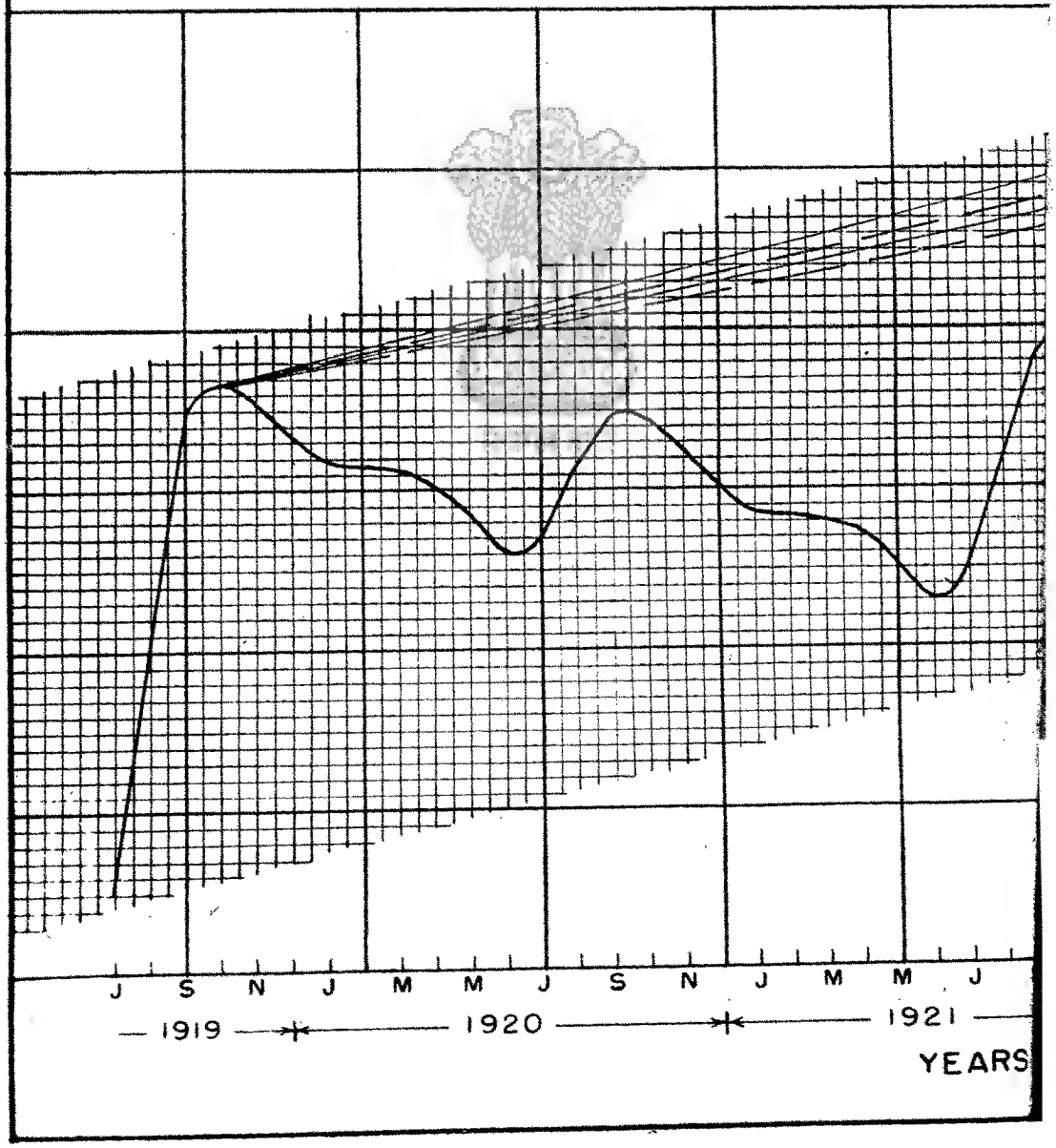
(About 90 %

STORAGE 28.22

25.92

24.49

22.52



AT NAVAGAM

)R" CRITICAL CYCLE

AF (including 1.92 MAF of
igation abstraction
) % availability)